EASTERN SENEGAL RANGE AND LIVESTOCK PROJECT

Final Monitoring and Evaluation Report

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Center for Research on Economic Development
University of Michigan
1985

Ecological Sanitation and Reuse Out Development Project

Synthesis

EASTERN SENEGAL RANGE AND LIVESTOCK DEVELOPMENT PROJECT

SYNTHESIS REPORT

by

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Prepared by
Center for Research on Economic Development
University of Michigan

for

U.S. Agency for International Development (USAID)
Contract No. 685-0202-C-00-2137-00

February 1985

Published by

Center for Research on Economic Development
307 Lorch Hall
University of Michigan
Ann Arbor, Michigan 48109-1220 U.S.A.

PREFACE AND ACKNOWLEDGMENTS

This report presents the findings of the monitoring and evaluation effort for the Eastern Senegal Range and Livestock Project. Aside from conventional activities, the early design included original features -- especially water catchment ponds -- expected to have significant experimental value.

The 1980-81 Project Review and Evaluation, however, highlighted shortcomings in extension delivery systems and a serious lack of baseline data; the latter made it impossible to gauge the impact of key interventions, and partly jeopardized the very justification for the project.

To address this deficiency, a team of researchers in range management, soils and water engineering, and rural anthropology, spent over eighteen months in the field. The work they did with the collaboration of project staff leads us to the conclusions that water ponds did not provide the expected level of benefits, and that fire control infrastructure allowed only for indirect -- although substantial -- gains. Other infrastructural investments have also had a broad positive impact on the area. Finally, the reorientation of extension services along rather aggressive lines made it perhaps the most successful of all activities.

In the final analysis, we wish to stress the appropriateness of integrating from the very start, solid and permanent monitoring programs into development projects. Given inevitable uncertainties at the earliest stages, they reveal the extent of design flaws early in project history, without much of the trauma associated with formal evaluations. They also provide critical management information in a timely fashion over the project life, as well as data allowing transferability of valuable experiences across projects.

This document includes each field researcher's final report, and a synthesis. The individual reports necessarily present issues from each specialist's professional viewpoint, so that the synthesis attempts to make a blending of outlooks as well as a summary of conclusions.

Carrying out such a task can only be done with dedicated collaboration and generous help from a large number of people: national and USAID project staff, beneficiaries, local authorities, other researchers in Senegal and the United States, and CRED personnel. Some acknowledgments are made in the separate reports, but with apologies to the many who cannot be mentioned individually, we would like to express here our deep thanks to Dr. Abdoullaye B. Niang, and Mr. Larry Harms, Project Director and USAID Project Officer, respectively, as well as their staffs, for their untiring willingness to cooperate with our team. We are also very grateful to the young men and women who gathered

information through the long months, under very difficult conditions, and to their supervisors, Daouda N'Diaye and Djibril Diop. Various researchers in Senegal have gladly shared their experience and talent to help this study, particularly at the National Livestock Research Laboratory, at the PEDSO livestock project, and at ORANA, the National Office for Research on Food Consumption and Nutrition.

At CRED, we benefitted from the motivating leadership provided by research project director, Edgar Ariza-Nino, and the ever-steady management hand of Sherry Cogswell. With her usual skill Carol Wilson directed the editing process, with the help of Patricia Humphrey and Becky Doyle. Many thanks also go to Jane McCormick who, as usual, provided extremely clear maps and graphs.

Most especially, however, we are grateful to the three field researchers, and their families (especially Sara Anderson-Thomas and Gay Morgan Allen), for their exceptional willingness and ability to work together and with other project staff under difficult conditions. Insofar as this research effort provides future guidance for this project's activities, and valuable lessons applicable to others, most of the credit unquestionably belongs to Maryam Niamir, Chief of Party and range manager; Allen Clark, soils and water engineer; and Patrick Thomas, rural anthropologist.

Henri P. Josserand
Ann Arbor, 1985

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I. INTRODUCTION AND BACKGROUND

I.1. THE PROJECT

This is the synthesis of three reports on monitoring and impact assessment for the Eastern Senegal Range and Livestock Project (hereafter known as the Bakel project), as amended. The three reports cover Range Management; Soils and Water Engineering; and the Socioeconomic Study.

The original purpose of the project (December 1974), was to protect range resources and improve livestock production in the Toulekedi/Sarre Zone of Eastern Senegal, south of the town of Bakel. The project was to provide and test a model for an integrated approach to livestock development which might be expanded to other parts of Senegal and the Sahel. The main components of the Logical Framework were as follows:

Project Purpose: Develop a replicable system of integrated stock and range management socially acceptable and economically viable.

Verifiable Indicators: Existence of range and stock, increased target area incomes, GOS capability to manage the system.

Means of Verification: "Proper" use of water-points, improved range conditions, improved milk production, cattle numbers kept under a proper ceiling, offtake rate up to 14%.

Necessary Assumptions: Support by the Government, no unusual constraints on production (e.g., weather). Nonuniqueness of the Bakel area.

Project Expected Output: Introduction of the concept of range and of livestock management, management capability demonstration, training, research.

This type of project was given high priority by the Government because of their willingness to get over the drought, their sectoral objective of rangeland control and development, and the new emphasis placed on an area of the country previously largely ignored. In the subsectoral scheme, the Easternmost part of the country, known as Senegal Oriental was to become a zone de naissage, or breeding area; young animals born there were to grow out in central and western Senegal.

The project itself was to follow a systemic approach encompassing livestock, vegetation and water resources, human needs, transportation and marketing, recognizing from early on that a major economic problem of the area was isolation and lack of transport and communications. Expected impacts on livestock were seen mostly in terms of higher fertility or calving rates, lower mortality, higher cattle weight and sales at an earlier age, larger herd size, increased sales, and higher milk output.

Most of the observations on land use and livestock management made in the mid-1970s were accurate and remain valid to this day. For example, problems with overgrazing and trailing, woodcutting, and bush fires, were well identified. Livestock management and farming practices compounding these difficulties were also noted; they still pertain. In response to this, the basic orientation given the project early on rested on a set of technical and managerial strategies. Some were comparable to measures commonly taken in other regional livestock projects, while others were original, untried in similar conditions.

The originality of the chief technical approach (construction of water catchment basins scattered throughout part of the project area) had two major implications: (a) the experimental nature of the project required an adequate monitoring and evaluation effort (on an ongoing basis, if possible) to gauge its appropriateness and potential replicability; and (b) the economic viability of the project was practically guaranteed by the value imputed to experimentation and demonstration effects.

As we shall see further in this synthesis, some of the technical and managerial recommendations turned out to be impractical or unsuitable to local conditions, while others remain quite valid and are supported by the longer-term work of our own researchers.

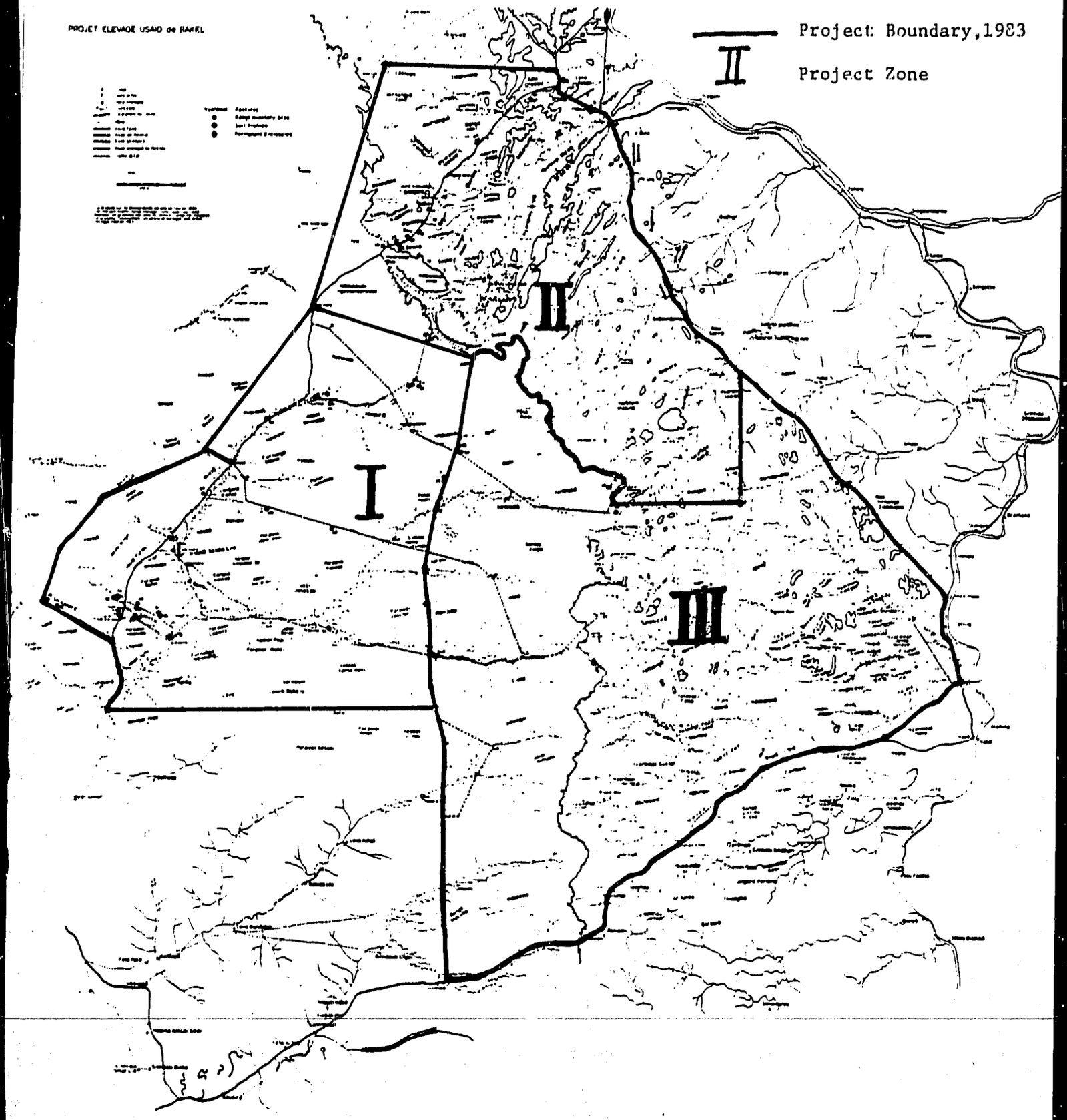
The project first major evaluation took place during the "Joint Assessment of USAID Assistance to Senegal," (1980). The main findings first cast some doubts on the appropriateness of certain technical approaches, especially with respect to control of bush fires. They also showed that the extension methods evolved over the first years of the project were very ineffective. Finally, it became clear that baseline information on livestock, range resources, and the socioeconomic situation in the area, was insufficient to substantiate many conclusions on the value of the project as an experiment.

In addition to an expansion and organization of the project area into three distinct zones (see Map 1.1), the project paper amendment identified four main types of tasks as part of the redesign effort: (a) to refine the application of the ponds to the specific range; (b) to introduce range condition monitoring and managing techniques; (c) to refine certain health and management services; and (d) to refine project management according to this set of goals.

With particular respect to monitoring and evaluation there were two main objectives:

- To assess the net effect of project interventions and determine the economic viability and potential for continuation in the same area, or replication elsewhere;

Map 1.1. Map of the Project Area as of 1982



- To use the information to concurrently regulate animal numbers to range-carrying capacity and water supply, that is, to design and test a Range Management Plan.

These two points therefore traced the overall course of research done in the field for over eighteen months by the CRED team: a range manager (Chief of Party), an hydrologist/engineer, and a rural anthropologist. They were backstopped by Senegalese and USAID project officers and staff, and at the University of Michigan by a research project director (agricultural economist), and a socioeconomic research supervisor (natural resource economist).

1.2. RESEARCH APPROACH

1.2.1. Range Management

The range management researcher started work in the area in November 1982. She originally faced a lack of systematic data on range resources, as previous technicians had tended to concentrate on particular types of species (lignous, for instance) and specific areas. During her first year of work on the project, she therefore concentrated on livestock and range management systems; the second year including a more equal balance of research and experimentation on a pilot scale.

Resources studied covered soils, vegetation, water resources and agricultural land use, as they were affected by the climate and geology of the area. The range resource inventory was based on 36 sample sites surveyed over two years and manual interpretation of aerial photographs. Vegetation was classified into 11 types, and the first detailed soil and vegetation mapping for the overall project area was done. The key map shows how vegetation is linked to soil types. This is most meaningful for long-term monitoring and planning, because although the composition herbaceous species varies much from year to year, there is more stability in vegetation composition when mapping units are based on soil classification. In particular, variations in woody species correlate best with soil type in the long run.

A number of survey efforts aimed to assess overall range productivity. These included clippings and studies of biomass use and loss, the measurable extent and impact of bush fires on regrowth, nutritive analysis of forage, succession and retrogression studies for specific communities, an assessment of degrees and extent of denudation around villages, and experimentation with five main techniques promoting revegetation. Some trials were also carried out for the introduction of new tree, forage and crop species.

Livestock management information was collected through interviews, observation, and dedicated monitoring programs on herding practices, transhumance, grazing patterns of unsupervised cattle and bite-count surveys, fecal analysis to determine the composition of cattle diet, and use of water ponds by livestock. In addition, chemical analysis of fresh milk was carried out at the ORANA (Office de Recherche sur l'Alimentation et la Nutrition en Afrique) in Dakar.

1.2.2. Soils and Water Engineering

The hydrologist/engineer worked in the project area from June 1983 through May 1984. His primary research task was to study the hydrology of 18 ponds built by the project over the years. This required the collection of data on rainfall, storm runoff volume, livestock usage, pond water levels and sedimentation rates.

He was further expected to supervise the construction of six new ponds by a local contractor. During that time he also completed an additional pond with the project's own heavy equipment, used the same to remove sediment from old ponds, and deepen a natural pond (koli mare). In addition he was responsible for continued construction of firebreaks and access roads, and for a review of ground water resources. Finally, he made some observations on soil erosion.

1.2.3. Socioeconomic Study

The socioeconomic study spanned the period of January 1983 to May 1984. Some baseline data had been collected during earlier phases of the project, but it covered only a few specific topics, focussed on part of the project zone, and was incomplete. Without the option of doing straightforward before/after comparisons, the best approach was to gain as clear an understanding as possible of the overall situation, and a much sharper appreciation for specific constraints to development.

The information collected during the socioeconomic study therefore covered areas most likely to provide better insights into the socioeconomic, cultural and physical milieus. Interviews and surveys were carried out on 20 households in a dozen of villages; chief topics included:

Human demography: household composition, including primary and secondary occupations, level of education, and migration experience.

Agricultural and livestock calendars: once, for all surveyed households.

Field surveys: measurements of all fields of all surveyed households, and information on crops cultivated, fallow, and production.

Food consumption: each of the 120 surveyed households was followed for three consecutive days, at three different seasons of the year. Type and quantity of food

prepared, and the number of consumers, including pregnant and nursing women were recorded.

Sales of farm products: for all households, every two weeks, recorded sales of crop and livestock products, including milk.

Purchases of food items: every fortnight, for all households.

Health status and demographic change over the survey period: semimonthly interviews for each followed household.

Evolution of livestock holdings: semimonthly interviews on changes in holdings of large and small ruminants.

Agricultural labor allocation: 30 households were interviewed daily for 120 days. Information covered time spent by family and others in the household's fields, and their activities.

Life histories of cows: for 402 cows, life histories including age, number of offspring, their outcome, data on survivors, etc.

Livestock census: a one-time census of livestock holdings of all surveyed households.

Nonagricultural income: unscheduled interviews of all surveyed households, including activity, season, and estimated revenue.

Infant mortality: for all surveyed households, pregnancy histories of women, number of miscarriages, infant deaths, etc.

Migration: unscheduled interviews in all households on the number of years abroad, location, status and place of employment, and current situation.

Livestock plays a pervading role in the people's social and economic lives, and one had to integrate the social system into resource management plans. Some of the information collected by the socioeconomic team was therefore useful to the range management researcher, and vice-versa.

Gathering information over the three project zones involved a combination of data collection approaches and processes. In addition to the principal field researchers, several teams of part-time or full-time enumerators were required. These included junior extension staff assigned to villages, women enumerators hired and trained separately, also assigned to certain villages, and small teams working on specific areas (measuring fields, tracking labor allocation, collecting cattle life histories).

The principal field researcher also had two close assistants; one supervised enumerators and conducted specific surveys. The other verified data and entered it into a portable microcomputer. This computer (Hewlett-Packard 85) was operating on batteries powered by a combination of solar panels and occasional charge from the Mbaniou base's nighttime electrical generator.

2. THE SETTING AND THE PEOPLE

2.1. OVERALL ENVIRONMENT

A recent study of the Bakel area has documented the recurring pattern of subsistence crises that spanned an 88-year period from 1858 to 1946. According to administrative documents and oral histories of this period there have been five major famines lasting eight months or more, three famines stretching over two agricultural seasons, nineteen famines lasting three to eight months, and twelve periods of hardship that lasted about two months each (Chastanet, 1982:29).

Only the northern section of the Ololdou Zone would have been included in the study, and our own experience has shown that there is wide variations in rainfall patterns in the region. The fact remains, however, that the area has been plagued with a recurring pattern of subsistence crises over the last hundred years. The social structures and the economic strategies of the local population reflect this fact.

Rainfall in the project area depends to a large extent on the seasonal movements of the "intertropical convergence zone." Most precipitation occurs between June and October; the occasional rainstorms of January through March do not provide more than a trace of rain, drying immediately once the sun reappears. The rainfall map of Senegal indicates that the area receives 500 to 600 mm of precipitation per year; during the 1983-84 survey period of one year, precipitation was about 475 mm. Not only is there high variability from one year to the next, there is also high variability between months, and in space at any one time. The engineer/soil scientist, for instance, reported much difference in recorded rainfall from gauges located 500 meters apart.

The extreme uncertainty of rainfall patterns strongly influences the social and economic lives of the population in the project zones. Between the two villages of Mbaniou and Ndia, only seven kilometers apart on a north-south axis, there were on several occasions differences of 20 to 50 mm in rainfall. The irregular timing of rains can be highly disruptive as well. During the 1983 agricultural season, the maize crop was almost entirely lost throughout the project area mainly because critical rains did not occur at the right time.

The most important physical feature of the project area is the sharp difference in soils, vegetation, and water resources, between the Gambia River and the Senegal River watersheds. The two basins are separated by an escarpment line running approximately north-south. The height of this escarpment does not exceed 70 meters, but it exerts a strong influence on the ecology of the area. The Gambia Basin (west of the escarpment)

is characterized by a mottled and clayey sedimentary rock, covered by 1 to 4 meters layer of ironstone. The Senegal River Basin, on the other hand, has seen a gradual erosion of the continental terminal by the river and its tributaries, so that the bedrock is exposed in many areas. Along the eastern edge of the continental terminal, the more advanced erosion process has left a deep sandy area, 1 to 2 kilometers in width.

The project area covers approximately 260,000 hectares. It is administratively divided into three zones: the oldest zone, Mbaniou, and two new zones, designated as the Ololdou and Sinthiou Fissa Zones, which were added to the project in 1980. At its widest points the project area is approximately one hundred kilometers wide by one hundred kilometers long (see Map 1.1.).

2.1.2. Mbaniou Zone

Population is concentrated along two axes. There are a number of villages along the Bakel-Mbaniou-Goudiry road, and a number of villages along an east-west axis starting from Mbaniou. These villages have been linked by a project firebreak. The thirteen villages in the area are all small, ranging in population from less than 100 to approximately 350 inhabitants.

2.1.2. Sinthiou Fissa Zone

The Sinthiou Fissa Zone has by far the largest number of villages; most are 10 to 15 kilometers from the Bakel-Kidira-Goudiry road. The major villages of Bele, Sinthiou Fissa and Youpe Hamady are along the road itself, but an important line of villages is located just east of the escarpment. Some of these have major problems with water for human consumption. The villages of Wali Diala, Birfal,and Gourel Maman Ndieye, are totally abandoned during the dry season.

2.1.3. Ololdou Zone

The Ololdou Zone has two main clusters of villages. The northernmost of these consist of small villages along the Bakel-Mbaniou road between Bakel and the escarpment. These villages range in population from a 125 to 150 or less. The second concentration of villages lies along the Bakel-Kidira road where the villages of Bema and Sarre are located. The largest community in the zone is the small town of Gabou.

2.2. WATER RESOURCES

Groundwater conditions are quite different on either side of the escarpment dividing the project zone into the Senegal River Basin and the Gambia Basin watersheds. The

Senegal River Basin watershed includes the area east of the escarpment: the Sinthiou Fissa Zone and most of the Ololdou Zone. Water is found in or above rock, usually schist, and there seems to be little potential for high yielding wells in the area. The best approach is probably to deepen and improve existing wells to increase their supply. There are two exceptions to this in this watershed, near the settlements of Gabou and Ololdou. Both are located in basin bottoms surrounded by hills, and have good wells feeding from geological faults.

The Gambia River Basin essentially covers the Mbaniou Zone, geologically called the continental terminal. It consists of oceanic sediments overlaying bedrock. Throughout the zone there is a sandy layer starting at a depth of 30 to 40 meters, which contains significant quantities of water. It is sometimes broken by strata of sandstone or large rock fragments, but generally seems to yield more water the deeper it is penetrated. Measurements made over the past several years by a FAO hydrologist indicate little or no drop in the water table elevation. Therefore, there seems to be a good supply of water in the aquifer.

Most wells in the Mbaniou Zone are large bore wells dug by local craftsmen. Above the water level, concrete is plastered over wire netting and reinforcing rod, while below the water, pipe sections fabricated on the surface are sunk into the water-bearing strata. These local wells are inadequate; they do not sufficiently penetrate the aquifer, and prefabricated pipe sections collapse after a short time.

The dependence of agricultural activity on groundwater as well as on timely rainfall is exemplified in the Sinthiou Fissa Zone by a group of villages located just east of the escarpment. These are inhabited only during the growing season as long as standing water is available. When this runs out, the three villages of Birfal, Gourel Maman Ndieye, and Waly Diala become deserted, and their populations fall back on the "mother village" of Ourousoulé for the remainder of the year.

2.3. RANGE RESOURCES

The range manager's major objective was to study the dynamics of vegetation communities, in terms of ecology and exploitation. She had to concentrate on herbaceous species, which is unfortunate, since lignous species provide part of the cattle's diet. Range resources assessment was done over two consecutive rainy seasons.

The project area pastures are mostly annual herbaceous communities of moderate total biomass, with a good floral mixture of palatable species, especially a wide range of legumes. They generally have a good tree/shrub density, also of high palatability. This

makes them suitable to a wide range of domestic and wildlife animals. The area's rainfall patterns, however, result in pronounced variations in availability and distribution of the annual biomass. The lack of control over such factors means that management strategies will have to remain flexible and acutely aware of small changes in the productivity of the land.

2.3.1. Community Productivity Studies

To obtain an idea of Net Primary Productivity (NPP) of certain communities, clipping studies were carried out in the 1983 rainy season to simulate the effects of continuous grazing at different intensities. Some studies done in 1984 attempted to reflect discontinuous or rest-rotation grazing. The studies were done on the three major range types of the Gambia Basin (ironstone, floodplains, and streambeds), on the foothill ranges of the Senegal Basin, and on a stand of Andropogon gayanus, found in occasional patches on either side of the escarpment. Certain findings and implications are integrated into the proposed Range Management Plan.

Biomass is lost to grazing by livestock and wildlife, wind, and insect damage (especially termites), but although termites can be major competitors for forage, they play very important and positive ecological roles. In addition to herbaceous species, cattle consume litter and woody litter; they also browse on certain leaves and fruit.

Bush fires constitute another key factor affecting amount of standing biomass and range productivity. A very high percentage of the rangelands are burned every year. Manual interpretation of remote sensing imagery and ground surveys by both Dickie and Niamir suggest that about half of the range in the Mbaniou and Sinthiou Fissa Zones of the project area is burned yearly. Some fires are early (October) and not very destructive, but most are set from November through January, and destroy much of the biomass. Late fires occurring from February through May are not as serious because by then, most of the biomass is gone. The effect of fires on vegetation is somewhat determined by soil types, but the conclusion is that although a pattern of fires occurring every 3-5 years would probably be beneficial, the current pattern of burning is not, and it leads to an increase in less desirable bushes and to a decrease in leguminous species.

2.3.2. Succession and Retrogression Studies

Nearly ten percent of the project area is already denuded, and another ten percent is estimated to be degraded or in the process of denudation. Much of the research emphasized understanding the causes, processes and impacts of rangeland degradation.

There are four major reasons for the reduction in soil cover in the project zone: drought, reduction in tree cover, features of the cultivation system, and grazing/trampling by livestock.

Drought has periodically afflicted the area, and will continue to do so. It weakens the productivity of the plant community so that the safety margin between normal and excessive exploitation is reduced. Although drought was not the exclusive causal agent, it compounded the effects of other factors.

Live trees are cut for construction of fences, houses and barns. The tree cover not only protects the soil from high winds and raindrop impact, it also provides shade for the herbaceous layer, without which most species cannot withstand the 2 to 3-week dry spells frequent in the rainy season.

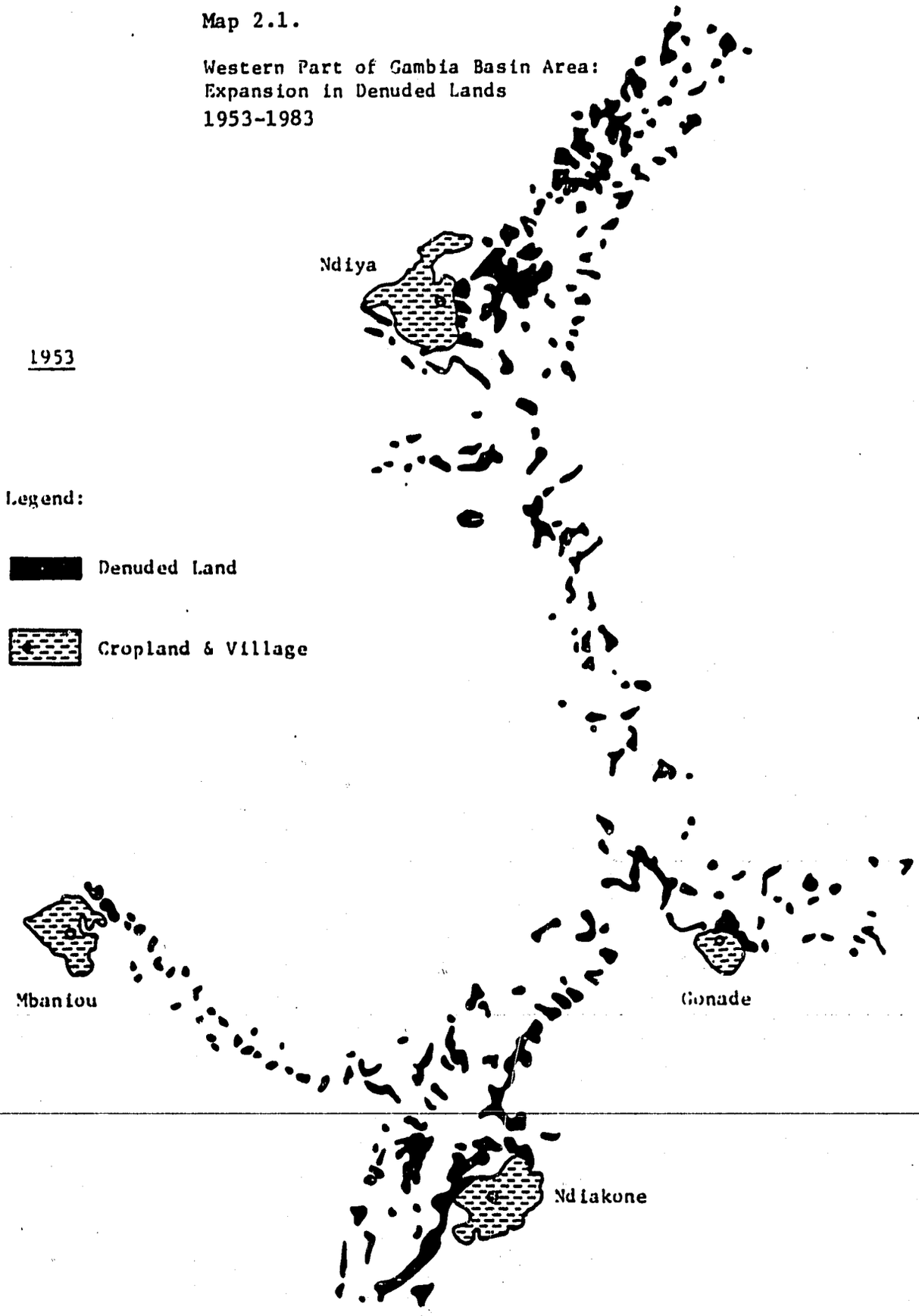
By far the most important factor in soil degradation of floodplains is grazing and trampling by livestock. Because of the nature of the soils and of grazing patterns, grazing and trampling are much more destructive in the rainy season than in the dry season. The retrogression of vegetation communities thus varies both according to season and type of livestock. During the dry season, sheep and goats tend to be more destructive since they browse on surviving bushes and trees located in floodplains, 3 to 5 km away from villages. Paradoxically, it is in the rainy season that the destructive influence of large ruminants is most important. At that time, floodplain and riparian range types support a variety of palatable grasses and legumes, and cattle congregate in these areas. The fragile slopes of floodplains are thus heavily trampled, which gradually results in a compaction of the subsoil. It is only at the end of the rainy season, when grasses enter their flowering stage, that cattle move to the ironstone plateau areas but by then, the damage has been done.

Three salient points emerge from the studies on retrogression in herbaceous and woody species. On the one hand, there is a decrease in total herbaceous biomass associated with increasing grazing pressure. Secondly, there is a general trend first toward bushes and hardy dicots, and then toward plants with deeper roots that can withstand the relative decrease in soil moisture. Thirdly, the exact sequence of plants depends very much on the soil type.

Aerial photo interpretation of the project zone shows that in 1983 a total of 22,674 hectares of land were already denuded, of which 14 percent were in the Gambia Basin, and the remainder in the Senegal Basin, especially close to the Senegal River. A comparison of aerial photos from 1953 and 1983 (available only for the Gambia Basin) shows that the yearly rate of increase in denuded land area is on the order of 5.65 hectares per village per year in the Gambia Basin (see Map 2.1. and Table 2.1.).

Map 2.1.

Western Part of Gambia Basin Area:
Expansion in Denuded Lands
1953-1983



Map 2.1. (cont.)

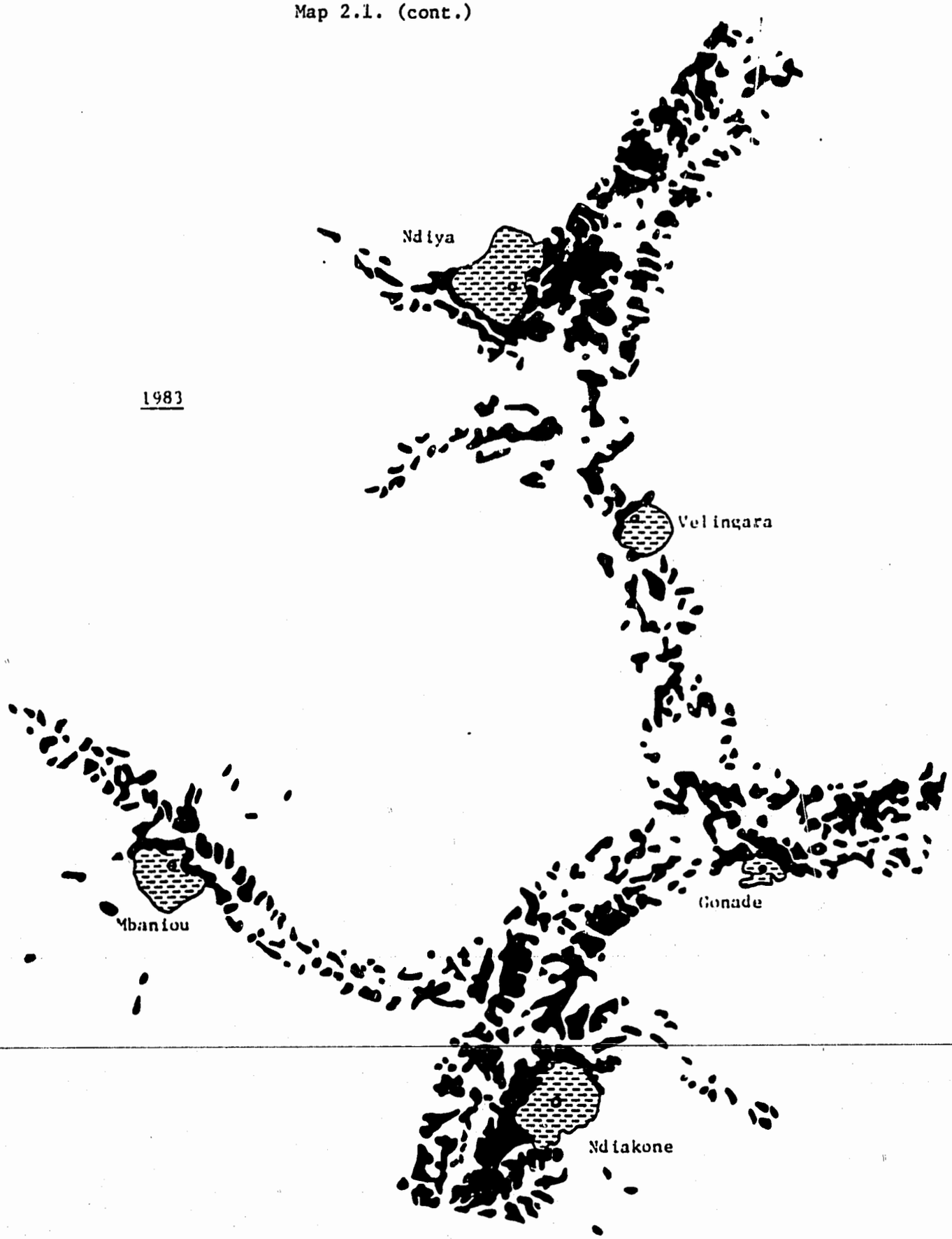


TABLE 2.1.

DENUDED LAND AREA IN GAMBIA BASIN, 1953-1983
(ha)

Village(s)	1953	1983	Difference ha	Difference %	Average Increase ha per year
Toulekedi	62.9	317.8	254.9	405	8.5
Boulel and Thieké	114.5	374.2	259.7	227	8.66
N'Diaye and Velingara	188.7	372.6	183.9	97	6.13
Mbaniou, Ndiakone and Gonadé	193.6	517.8	324.2	167	10.81
Diare M'Bolo, Garalla, Diare Maboubé and Medina Guiraye	316.2	1325.9	1009.7	319	33.66
Sowol	NA	235.5	--	--	--
Total (without Sowol)	875.9	2908.3	2032.4	232	67.75

SOURCE: Survey data.

2.3.3. Forage Nutritive Quality Analysis

There is relatively high quality feed intake during the rainy season, followed by very low quality feed during the dry season. Weight and milk production of cattle are very much affected by this cycle, whereas sheep and goats, because of their greater consumption of woody species maintain relatively constant weights year-round. During the rainy season both cattle and goats consume on the average a ration high in Digestible Crude Protein Content (DCP), equal or superior to the theoretical requirements for maintenance and lactation, but not sufficient for 100 gm/day gains in live-weight.

During the dry season cattle switch to fruit from certain trees, leaves of nondeciduous trees, and young shoots of other trees. At the beginning of the dry season, DCP decreases but remains above requirements for lactation. From January through the end of the dry season, cattle consume less and less DCP, maintaining bare maintenance requirements, and losing weight gained during the rainy season. Cows continuing to lactate into the dry season are thus probably doing so through increased weight loss. Goats, on the other hand, consume enough to maintain both weight and lactation requirements throughout the dry season.

2.3.4. Range Stocking Capacity and Potential

Theoretical calculations of the actual stocking capacities in the project area were made by comparing estimated forage needs of livestock and amount of forage available as measured through biomass studies. This method is not wholly satisfactory because it only provides figures on the dry season capacity. It also assumes that livestock have access to all parts of the range, regardless of water resources, and accounts neither for detailed variations in rangeland productivity nor the contribution of trees and shrubs to the diet of animals. Calculated stocking capacities can therefore be used only as a general guideline to the overall range productivity.

With the present uneven water distribution, losses of up to 50 percent in yearly biomass due to bush fires, and 10 percent of denuded land surfaces, the current stocking rate is very close to our estimate of stocking capacity for the dry season of a bad year. In good years, the stocking capacity would certainly be higher, but over the past decade there have been more bad than good years, so that the stocking rate should not be allowed to increase beyond its current level. Accordingly, until key resource constraints are relaxed, the stocking rate should be kept under 10,000 UBT/dry season in the Gambia Basin, and 11,000 UBT/dry season in the Senegal Basin (this applies to all livestock, not merely cattle).

2.4. PROJECT BENEFICIARIES

2.4.1. Ethnic Composition

The majority of the population in the project area considers itself Hal Pulaar of Fulani and Toucouleur descent. In a few other villages there is a very small percentage of non-Fulani or non-Toucouleur people of undetermined caste. These small groups can be found primarily in border villages of the Ololdou and Sinthiou Fissa Zones. The study sample was drawn to reflect the small rural character of the project area. The villages chosen are primarily monoethnic, and reflect the dominance of the Toucouleur.

2.4.2. Social Structure

Social organization follows the hierarchical stratified caste system of the Toucouleur, where the Torodo priestly caste holds the superior position. The Torodo are followed by the Sebbe, who prior to Islamization had been the ruling group. Within the caste there are several levels of rulers, soldiers, courtiers, and counselors, all of whom are considered freemen. After the freemen caste come the Maboube or craftsmen, and

the genealogical musicians. Finally, the slave caste consists of all strata of other ethnic groups subjugated by the followers of El Hadj Malick Sy, or sold by their captors to families living in the Boundou.

Villages reflects the social organization of Toucouleur society. Slave and artisanal castes are under the leadership of the leading Torodo family. However, the most obvious economic manifestations of the caste system appear to have receded. Social structural obligations still play an important role, but artisanal and slave castes are not under strict economic obligations to upper castes.

2.4.3. Social Structural Importance of Livestock

The importance of livestock is evident from the role cattle play in centralizing the authority of the head of household. Cattle are the seat of status and prestige, and an integral part of rites of passage. The head of household has authority over the family herd, which generally includes animals belonging to various family members. A typical herd consists of animals that belong to the head of household, his wives, and sons. There may also be animals belonging to his brothers, their wives, and children. Other relatives or friends can also consign animals to his care.

Cattle play a major role in marriage, are sacrificed to mark events such as the groundbreaking for a new house, or may be offered to a griot who has come to praise and affirm the family's noble and historic genealogy.

At the death of a herd owner all his personal animals are pooled. They are then divided into nine equal parts. One part is divided among the wives of the deceased. The remaining eight parts are divided among the children. Daughters receive half of the sons' shares. When a woman has died, the procedure is similar except that her herd is divided into seven equal parts. The seventh is given to the husband, and the six remaining parts are divided among the children, daughters receiving half as much as sons.

2.4.4. Basic Demographic and Economic Indicators

Figure 2.1. shows the age and sex distribution of the surveyed population, numbering 1,239. The most notable feature is the gap created by long-distance migration in the 30-35 and 35-40 age groups for males; this has important implications for family labor available both for farming and livestock herding in the area. Tables 2.2. through 2.5. summarize key statistics for each of the three zones. The average household size does not vary significantly from just under 8 members across zones. The number of household members currently away for wage employment does vary across zones, with means of 0.65 migrants per household in the Mbaniou Zone, 1.81 in the Sinthiou Fissa Zone, and of 1.12

in the Ololdou Zone. The number of former migrants in each zone suggests that out-migration is a more recent and extensive phenomenon in the Ololdou Zone, possibly because of more limited local opportunities.

Males clearly consider farming as their primary activity, herding being the most common secondary activity cited. Women consider homemaking and farming as their primary and secondary activities, the next most important activity being small trade. The relatively limited extent of occupations other than farming and herding (especially trades and crafts) is due to the particularly underdeveloped and isolated character of the project

TABLE 2.2.

HOUSEHOLD SUMMARY STATISTICS, ALL ZONES

Variable	Mean	Stand. Dev.	% Conf. Interval
Number of Household Members	7.98	3.5	7.4 - 8.5
Number of Current Migrants	.81	1.05	.65 - .96
Number of Former Migrants	.31	.54	.23 - .39
Area Cultivated (ha)	1.24	1.16	1.06 - 1.41
Harvest Index	100	-	-
Agricultural Sales Index	100	-	-
Food Purchases Index	100	-	-
Household Cattle	49.5	41.1	42.7 - 56.2
Household Small Ruminants	27.4	21	-

TABLE 2.3.

HOUSEHOLD SUMMARY STATISTICS, MBANIOU ZONE

Variable	Mean	Stand. Dev.	% Conf. Interval
Number of Household Members	7.85	3.6	6.9 - 8.7
Number of Current Migrants	.65	.8	.46 - .83
Number of Former Migrants	.35	.55	.22 - .48
Area Cultivated (ha)	1.45	1.4	1.1 - 1.8
Harvest Index	150	-	-
Agricultural Sales Index	117	-	-
Food Purchases Index	114	-	-
Household Cattle	58	.51	43.8 - 72.1
Household Small Ruminants	23.2	18.2	-

TABLE 2.4.

HOUSEHOLD SUMMARY STATISTICS, SINTHIOU FISSA ZONE

Variable	Mean	Stand. Dev.	% Conf. Interval
Number of Household Members	8.2	3.7	6.9 - 9.4
Number of Current Migrants	.81	1.2	.44 - 1.2
Number of Former Migrants	.41	.6	.21 - .61
Area Cultivated (ha)	1.18	.84	.95 - 1.4
Harvest Index	a	-	-
Agricultural Sales Index	65	-	-
Food Purchases Index	73.5	-	-
Household Cattle	47.2	36.5	36.3 - 58.2
Household Small Ruminants	16.1	10.7	-

TABLE 2.5.

HOUSEHOLD SUMMARY STATISTICS, OLOLDOU ZONE

Variable	Mean	Stand. Dev.	% Conf. Interval
Number of Household Members	8.1	3.2	7.1 - 9.1
Number of Current Migrants	1.12	1.2	.77 - 1.5
Number of Former Migrants	.15	.3	.04 - .25
Area Cultivated (ha)	.95	.81	.7 - 1.2
Harvest Index	82	-	-
Agricultural Sales Index	107.6	-	-
Food Purchases Index	99.4	-	-
Household Cattle	42.1	31.2	32.9 - 51.3
Household Small Ruminants	51.6	38.4	-

area. As explained in detail in the socioeconomic report, this situation is changing rapidly; money sent back by migrants is often being used to open village shops, for instance. Another area where significant change is taking place is that of education. The functional literacy program established through the project has probably been its most successful extension service, although there remain pronounced difference in school attendance between the sexes.

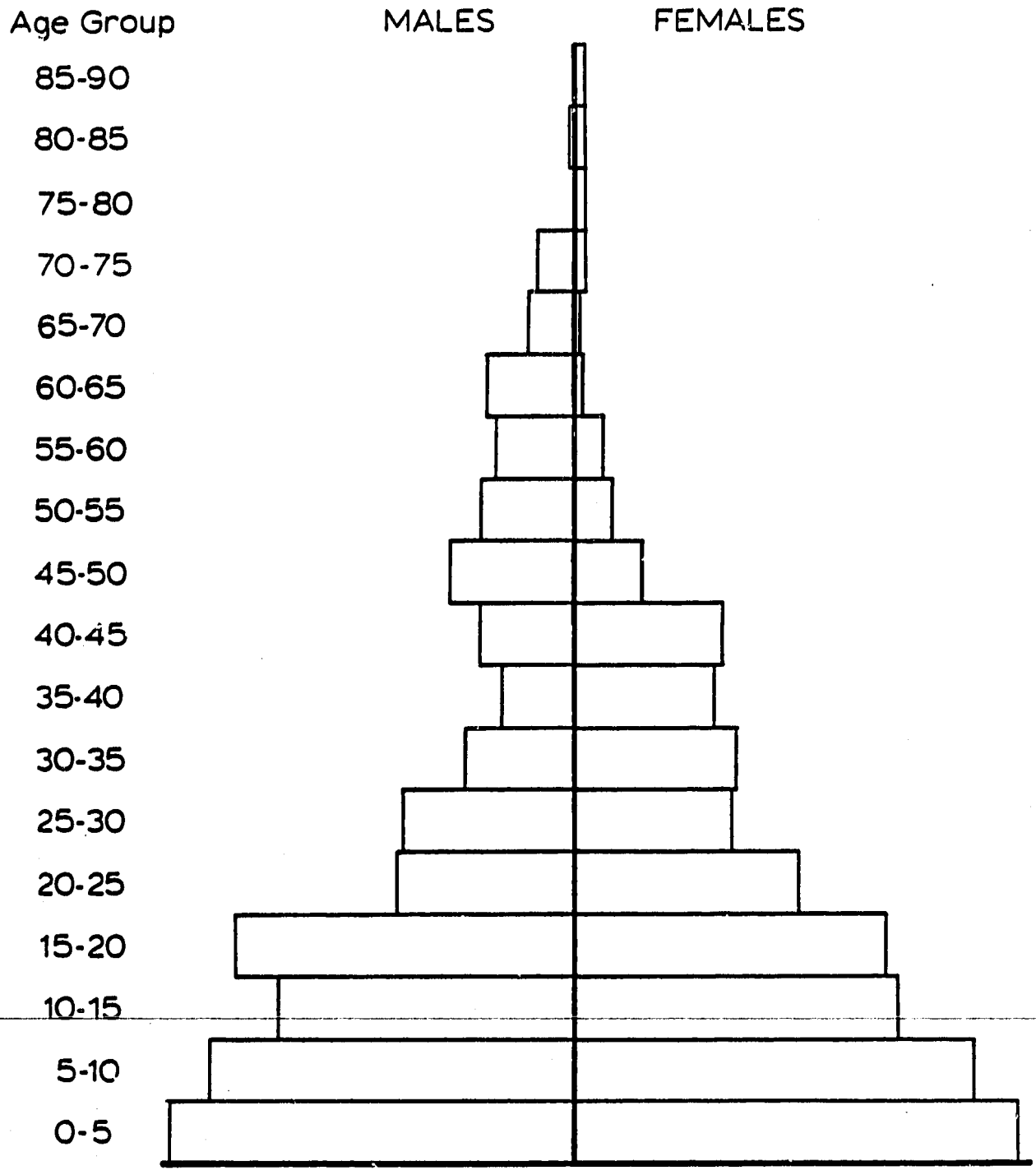
2.4.5. Agriculture

2.4.5.1. Background

The economic system of the project area is firmly based on the symbiotic relationship between agriculture and livestock. The Toucouleur of the Boundou were agropastoralists before moving into the area and have continued their traditional pattern of livelihood. Village histories collected during the research reflect also suggest that in many cases, the original settlements were temporary, inhabitated only during the agricultural season. These villages became permanent later as sources of water were developed and the soil proved to be good for agriculture. In all interviews concerning the choice of sites for villages we were told that the presence of good pasture in the area played an important role in the decision.

Figure 2.1.

Age/Sex Distribution of the Surveyed Population; All Zones



2.4.5.2. Social structure and labor allocation

Recurrent subsistence crises may well be a recent historical phenomenon, but the reliance on grain crops in the Sahel is not. Social organization reflects the need of the head of household to mobilize and depend on manpower from its members. According to the traditional pattern still in force in the project area, the senior brother wields authority over all his juniors and their progeny. Ideally, this would represent four generations of brothers, but most often two to three generations are under the leadership of the eldest brother. In some households, particularly those of village chiefs, there may be three generations under the leadership of the senior brother. This system theoretically permits the head of households to mobilize a maximum labor force for agriculture and other essential tasks. Women make important contributions to the family stock of cereals, although they have traditionally been responsible for the cultivation of lowland rice, peanuts, and garden crops, primarily niébé and okra.

2.4.5.3. Agricultural production

In all project zones people see themselves as sedentarized agropastoralists, but the actual extent of farming is limited, especially in view of labor constraints. For example, the average area cultivated by households in the Mbaniou, Sinthiou Fissa and Ololdou Zones was of 1.45, 1.18 and 0.95 hectares, respectively. One should note that the figure given as the mean area cultivated per household does not hide much of a skewing effect in either direction; the distribution of land worked by individual families in the three zones is rather even. Still, these figures are quite low, even by comparison with other traditional farming societies of Senegal. The overall low level of cultivation reflects the fact that existing conditions make returns to agriculture precarious, and provide a lower return on investment than the chief alternatives, livestock raising and long-distance migration.

Differences between zones reflect differences in resource endowment and population pressure; Sinthiou Fissa and Ololdou in general have a lower agricultural potential than the Mbaniou Zone, and tend to rely slightly more on migration.

The order of importance for crops cultivated remains constant across zones; sorghum receives most of the acreage, 6 percent and 55 percent respectively in the Mbaniou and Sinthiou Fissa Zone, and up to 80 percent in the Ololdou zone, where very little millet is grown. Millet comes second in the Mbaniou and Sinthiou Fissa Zone (32 percent and 5 percent of acreage), followed by maize. Very little land is devoted to peanuts, except in the Sinthiou Fissa Zone. There is very little lowland rice cultivation in the project area

because of the lack of appropriate depressions and diminishing rainfall. However, where land and water permit (in the Ololdou zone), the tradition is maintained.

Farming does not follow complex rotation patterns, and the majority of fields are single cropped, although some interesting potential for cereal/cowpea association has been noted by the Range Management Researcher. The most common patterns of crop rotation show succession of cereal on cereal, peanuts being followed by either peanuts or a cereal, and rice necessarily cultivated in the same limited locations year after year.

As one might expect, agricultural labor allocation closely reflects the emphasis given to the various crops: sorghum, millet and maize, in decreasing order of importance. Hired labor is used on various fields, but not to a great extent. Millet, sorghum and maize receive about equal -- and relatively low -- shares of hired labor as a proportion of total labor input. The relatively low value of returns to labor in agriculture does not incite people to hire manpower to replace young adults away on migration. In fact, a good part of the hired labor allocated to fields in the rainy season actually consists of people hired to watch after herds at a different period of the year.

For the project area as a whole, yield figures ranged from 600 to 800 kg of sorghum per hectare, while for maize yields ranged from 530 to 1,280 kg per hectare. Millet yields, however, were only about 600 Kilograms per hectare. We found that obtaining yield data was a sensitive and difficult matter. In a couple of instances it would have been possible to weigh the total crop as it was being placed in the granary, but our request was denied.

In the project area, approximately 100 kilometers wide by 100 kilometers long, there are marked differences in agricultural calendars between the three zones. For instance, there is approximately a two-week interval between the sorghum harvest in the three zones. During the 1983 season the harvest first took place in the Mbaniou Zone, followed by the Ololdou and Sinthiou Fissa Zones.

2.4.5.4. Economic interdependence of agriculture and livestock

The essential feature agropastoralism is that agriculture and livestock play important complementary roles both in the subsistance and cash economies. In terms of agriculture, herds are rotated over fields to benefit from their manure. As soon as the crops have been harvested and sorghum stalks needed for fencing and shading set aside, the herds are allowed to feed on the stalks that remains, initiating the manuring process for the next year.

Periods of high labor demand for livestock occur primarily at times of low demand for agricultural labor. This is true with the exception of the last weeks of the dry season

when field preparation and the drawing of water for the herds must be done simultaneously. Some labor is also needed to herd animals at bush camp while crops are maturing.

Livestock accumulation plays an important dual role. Livestock on the hoof is first a saving that can be sold in times of need. Accumulation of livestock is also a form of risk aversion and investment. A large number of cattle can minimize the losses that may occur from disease, drought or attacks on the herd by predators.

The important role played by agriculture as a means of cattle accumulation is being changed by worsening climatic conditions, and the difficulty of accumulating a grain surplus. Migration appears to have taken over the role played by grain accumulation in the past. Labor migration brings in cash that can be used to fill the subsistance gap in a bad year, or to invest in cattle.

2.4.6. Livestock

2.4.6.1. Typology and extent of herds and flocks

Cattle in the project area represent a cross between Bos indicus and Bos taurus-type animals; they are shorter than the pure Sahelian Zebu, but taller than N'Dama-type cattle found further south. The local breed is known as Diacori. Small ruminants are of the lower Sahelian Djallonke-type, some tall Djallonke-like goats called Ndogoota.

Table 2.5. shows the average size of cattle and small ruminants holding per household, for each project zone in 1984.

TABLE 2.6.

LIVESTOCK OWNERSHIP BY ZONE, 1984
(Average No. of Head/Household)

	Cattle	Sheep/Goats
Mbaniou	58	23.2
Sinthiou Fissa	47.2	16.1
Ololdou	42.1	51.6

The emphasis on small ruminants in the Ololdou Zone is most likely due to less abundant and lower quality forage resources than in the other zones. In terms of distribution, there is naturally some unevenness in livestock ownership between families, especially in the Mbaniou Zone, but not to an extreme degree. The most striking example

of unevenness in cattle distribution does not in fact appear in these numbers. Cattle ownership in the village of Diare M'Bolo, in the Mbaniou Zone is much higher than other communities, because of its social status and good marketing connections. However, this cannot be precisely documented because the total size of Diare M'Bolo herds could only be estimated, rather than surveyed, as was the case for the other villages.

The livestock census carried out for surveyed households, nevertheless, allows us to answer a critical question: "has the size of herds in the project area increased significantly over the last few years?" Table 2.6. suggests that it did not, at least in the Mbaniou Zone, which received most of the livestock-oriented project interventions.

TABLE 2.7.

COMPARISON OF HERD/FLOCK SIZE PER HOUSEHOLD, 1976-1984

	1976	1984
Cattle	66	58
Small ruminants	23.6	23.2

The overall size of herds and flocks has not significantly changed during the interval. One might suggest that although herd size has not changed, gains in fertility, survival and marketing of animals have taken place, and that increased benefits are being derived from the same equilibrium number of animals. Precise baseline data for small ruminants are not available, but in the case of cattle, a comparison of herd structure about eight years ago and today shows that age/sex distribution in standing cattle herds are closely matched.

The percentage of females in the herd (66 percent overall) suggests relatively heavy destocking of surviving males; the proportion of cows in total herds (46.8 percent) is very similar to that found in traditional cattle herds of the Senegalese Ferlo. It is actually difficult to reconcile the high proportion of females in herds and low observed rates of offtake until one realizes the importance of combined mortality of young and replacement purchases of heifers.

Data from the mid-1970s provided estimates of calf mortality in the 0-1 age group ranging anywhere from 5 to 40 percent per annum (the latter number being hardly consistent with historical sustenance of herds). Fertility and fecundity rates for cows were quoted as being from 52 to 57 percent annually. More systematic research by

project staff and our own teams suggest that calf mortality in the 0-1 age group is more on the order of 20 percent annually. The survey on life histories of cows, on the other hand, showed that the number of calvings per reformed cow ranges from 3 to 9, with a mean of 5 and a standard deviation of 1.3. This suggests a fecundity rate of over 60 percent per annum, and an average number of calvings equal or superior to what is found in traditional herds of the Senegalese Ferlo.

As we see further in the section on marketing, the offtake rate, expressed in animals sold as a percentage of the total herd is relatively low, estimated to be 6 to 8 percent (mostly males around age five). The data show that the reason for decreases in numbers of males could be attributed to sales (60 percent), and mortality (33 percent); for females, where sales are much lower in absolute numbers, sales accounted for 34 percent of decreases in numbers, and mortality, for 61.5 percent. Finally, for steers, which have reached ages where mortality is relatively low, sales accounted for 75 percent of decreases in the age group.

Both the survey of life histories for cows and the ongoing tracking of herd inventories indicated that purchases of cattle (essentially females) play an important role in maintaining herd sizes to the level people want to sustain. For males, purchases contributed 3.5 percent of additions, the rest being imputable to births within the herd. For females, on the other hand, over 10 percent of animals added to the herds were purchased, at ages ranging from three to four years.

The overall picture emerging from our data on herd composition and management practices suggests relatively high fertility and fecundity rates for cattle (the average number of miscarriages per reformed cow was 0.24). However, mortality in younger ages remains very high, which leads on the one hand, to a low actual offtake rate and on the other, to a need to maintain overall herd productivity by purchases of females in early reproductive ages. The net effect is the maintenance of cattle holdings near the current levels over time, and the maximization of benefits from cattle -- given high mortality rates -- by purchases of reproductive stock.

Everything leads us to believe that the further necessary decreases in mortality of young animals would translate into a reduction of outlays for the purchase of reproductive stock rather than sharp increases in herd numbers. Not only are heifer purchases a heavy drain on area households, the number of cattle families can currently carry is constrained by water resources and availability of manpower for the most labor-intensive tasks (especially watering animals in the dry season). It is also important to note that the pattern of heifer purchases is probably of long standing. Reducing calf mortality should therefore be considered as an objective having sizeable immediate impact on family

budgets, in addition to longer-term benefits. Herders are very much aware of this; in addition to bringing their animals in for free vaccination programs, they have spent relatively large sums buying cattle medicines sold at cost by the project.

Small ruminants make an important contribution to the local economy (15 percent of farm income), but actual and potential benefits are even further apart for them than in the case of cattle. Proportionally, for example, mortality is twice that of large ruminants. Animal health extension has traditionally concentrated on cattle, by and large ignoring sheep and goats, and this project is no exception.

2.4.6.2. Livestock marketing

Livestock marketing in the project area involves two parallel markets: (a) the traditional system by which people sell animals to travelling collectors (Dioula), or take animals themselves to a small regional market; and (b) marketing activities organized by the project. Several surveys, based on price comparisons between animals purchased by Dioula in the area and levels of transactions on nearby regional markets (Bakel, Tambacounda) suggest that the traditional marketing system is tolerably competitive and efficient. In fact, in the case of cattle, the project marketing program has not been able to offer prices substantially higher than those prevailing in the traditional system.

A description of the project's livestock marketing program is included later in the section on project interventions, in the Synthesis report.

2.4.7. Income and Well-being

In this context, income is defined as cash inflows from grain and cattle sales (agricultural income), from local nonagricultural activities, and remittances from migrants. In addition, the levels of food purchases and of actual food consumption over time for each surveyed family are used as indicators of food self-sufficiency and food intake.

2.4.7.1. Agricultural income

There has traditionally been a strong grain market in the area, especially for sorghum, but in recent years, the overall area has not been self-sufficient in cereals. Prior to the 1983 harvest, 27 metric tons of sorghum were brought in by project staff and sold in the Mbaniou Zone at 80 CFA/kg, 1 CFA above the purchase price (Diaw Djiby Dior, 1983). There were only cash transactions, and each head of household was limited to 200 kg of grain. The total cash outlay in the Mbaniou Zone for the 27 tons of sorghum was 2,160,000 CFA. This points out two very important facts. First, there was no grain surplus in 1983, and second, there was cash available to compensate for the subsistence deficit.

Data on agricultural sales collected from each of the 120 surveyed households for over a year confirm this. Table 2.7. clearly shows the relatively insignificant importance of millet, sorghum and peanut sales in total agricultural marketing for all zones (just over

TABLE 2.8.

MAIN AGRICULTURAL SALES, ALL ZONES

Product	Gross Income	%	$\bar{X}$ Unit Price
Cattle	13,114,580	80.1	49,000
Goats	1,521,352	9.4	7,760
Sheep	956,160	5.9	13,280
Millet	434,544	2.7	
Horses	65,000	.4	65,000
Peanuts	61,250	.3	61 kg
Chickens	34,008	.2	872
Donkeys	30,000	.2	10,000
Sorghum	11,100	.1	
Total	16,227,994	100	

three percent of total value). The bulk of agricultural income undoubtedly comes from livestock sales, and this money is primarily spent on grain purchases for millet, sorghum and maize from outside the region.

As we could see from Table 2.7., livestock makes up over 95% of agricultural sales. The second noteworthy point is that these sales nonetheless represent a very low level of offtake, considering that herds are not in a cycle of fast expansion. The estimated offtake rate for cattle is on the order of 6 to 8%, compared to a biological potential equilibrium offtake rate of over 10% in similar traditional systems. The observed structure of local herds, however, indicates maximum destocking, and even replacement of lost females through purchases; the conclusion is that calf mortality levels have remained high, and constitute the major obstacle to increased sales, rather than herd owners' attitudes or other factors. The same applies even more in the case of small ruminants, and for the same reasons.

2.4.7.2. Nonagricultural income

2.4.7.2.1. Small shops. The project area lacks either permanent or rotating produce and dry goods markets. The only permanent markets are in the major towns and

administrative centers of Bakel, Kidira and Goudiry. There is, however significant small-scale economic activity in villages. Even the smallest village in the area has what could loosely be called a shop. These are simpler versions of the small neighborhood stores found in most small towns of Senegal. Stock and supply are limited and sporadic as the shopkeeper rarely has a chance to make trips to Bakel, Kidira or Goudiry.

2.4.7.2.2. Crafts. Most villages have craftsmen: smiths, who make and sell axes and traditional farm tools; and woodcarvers who make bowls for milking, stools, mortars and pestles, items essential to every household. Some villages have matmakers and weavers, but these specialized skills are rare in the project area. The items produced are either sold locally or sold to retailers in nearby towns.

Some village also have other skilled craftsmen like traditional adobe house builders, who put up the kind of small houses commonly found in villages. Larger adobe or cement block structures are built by masons brought into the area on contract. They bring assistants and apprentices, while the owner provides materials like sand, cement, beams, roofing material, water, and adobe or cement blocks.

Several villages have specialized craftsmen in semi-permanent residence. In such cases they reside in the compound of the village chief, where they practice their craft. Having a silversmith or a tailor in residence, as do two villages, imparts a certain prestige to the community.

2.4.7.2.3. Bread ovens and other economic activities. There seems to be in the Boundou a certain taste for bread made of wheat flour baked in adobe ovens. Villages who have and maintain a functioning oven are proud of it, and people come from neighboring villages to buy bread. In several villages hunters sell meat to neighbors. On an irregular basis large or small ruminants are also butchered at the village, especially around feast days, when all the meat is likely to be sold.

Villages in the project zone are constantly visited by itinerant traders, healers and genealogical musicians. Cloth salesmen are seen on a regular basis, especially after the harvest, and before feast days. Travelling hardware salesmen offer used parts to repair horse carts and agricultural equipment. Some healers sell traditional medicines and herbs, or practice male circumcision and female excision.

The largest scale of economic activity for women in the project area is their operation of small village shops, but they are also involved in other, more traditional activities. Women are responsible for and own small ruminants, although as in the case of cattle, sales are generally negotiated through the head of household or some other male member of the compound.

Several villages in the area have women who belong to the potter caste. They make large and small water jars, open water pots, and couscous steamers. Their products are sold locally or in the major towns of the area. Women also sell what they have gathered or processed. Examples include the sale of fritters, tamarin fruit or of crushed dry baobab leaves.

2.4.7.3. Food purchases

The total amount spent on food purchases was highest in the Ololdou Zone; food purchases per household were equivalent, on the average, to 104,472 CFA Francs annually. In the Sinthiou Fissa zone, the total amount spent on food purchases was equivalent to about 4,455 CFA Francs; finally, the lowest food purchases of the Mbaniou Zone amounted to an average 7,438 CFA Francs per household per year. In spite of marked differences in the level of spending, its distribution over the range of items across zones is very similar. Five or six basic food items account everywhere for over 80 percent of purchases, in decreasing order of importance: millet, rice, peanuts, sugar, oil and dry fish. Not surprisingly, these are primary ingredients in the preparation of most common dishes consumed in the area.

The remainder of the purchased items is also typical of the kinds of foods consumed in the Boundou; the very limited amounts spent on animal protein derived from red and white meat are mostly offset by consumption of peanuts and dry fish in sauces, and by occasional slaughter of small stock raised by the family. One should note also the absence of reported transactions in sorghum and maize. The deficit in home cereal production is made up mostly by millet and rice purchases, rather than through the acquisition of additional sorghum or maize.

2.4.7.4. Food consumption

A dietary survey of all surveyed households was conducted for over a year; the basic rationale was that nutritional intake (even simply defined in terms of calories and protein) is a valid and reliable indicator of well-being in rural communities. Each surveyed household was followed for three consecutive days, three times a year. Prepared food was weighed and recorded before cooking, and the number of men, women and children partaking of each meal was noted. Women enumerators were also in charge of collecting from household women information on food purchases.

Given the age/sex structure of the surveyed population, we estimate the weighted average caloric requirement per "fully active" person to be about 2,300 Kcal per day (Latham, 19??). Observed levels of food consumption lead to lower estimates of

nutritional intake. For the surveyed population as a whole, Table 2.8. shows mean caloric intake to be 1,965 Kcal per person per day. Unadjusted protein intake is higher than the conventional norm of 30 to 35 required grams per person per day, but because of caloric deficiencies, part of it is certainly converted to energy, so that the actual proteic intake is much lower. One should also note that the range of nutritional intake among surveyed families is rather wide. The better-off 25% of households consumed at least 2,400 Kcal/person/day, while the least well-nourished 25% of households consumed less than 1,431 Kcal per person per day. Although the dietary survey did not include between meal food consumption (which can be quite significant, especially for women and children), the data suggest severe nutritional deficiencies in a relatively important proportion of families.

TABLE 2.9.

FOOD CONSUMPTION SUMMARY STATISTICS; ALL ZONES

	Mean	Stand. Dev.	.95 Conf. Interval
Kcal/per/day	1,965	743.6	1,819 - 2,111
Gr. prot/per/day	59.5	22.4	54.1 - 62.9

Since dietary intake was followed for over a year, it is possible to examine its evolution over the various seasons. Caloric intake is clearly lower at the end of the dry season, when food stores are exhausted, and at the time of most demanding agricultural labor. There is no doubt that agricultural productivity must suffer from this.

A comparison of mean nutritional intake across zones reveals significant differences. Lowest caloric and proteic intakes are observed in the Ololdou Zone, which has poorer range and agricultural resources than the other two (along with high rates of migration). The Mbaniou Zone comes second, with average caloric intake of just under 2,000 Kcal/person/day, close to satisfying requirements. The Sinthiou Fissa Zone has slightly higher levels of caloric and protein intakes.

Putting together what we know of these three zones leads to these conclusions: average nutritional intakes in the Mbaniou Zone are consistent with relatively very low food production on the farm, and lower out-migration, but highest reliance on livestock sales for agricultural income. The Sinthiou Fissa Zone has probably had the highest level of agricultural ouput (it was the only zone selling significant amounts of millet during the year), its lowest livestock sales are offset by the combination of more favorable

agricultural conditions -- at least in 1983-84 -- and the highest extent of migration. Finally, the Ololdou Zone had average livestock sales, but probably the greatest deficit in food production, which was not quite made up by remittances consistent with its second rank in out-migration.

2.4.8. Migration and Remittances

2.4.8.1. Historical foundation and background

The contemporary genesis of the Boundou's labor migration in general and to France in particular, lies in the migration pattern of the Soninke of the Goy. Their defeat by the French forced them to gain new sources of income; they worked as stokers on river steamers, eventually moving to ships plying the coast of Africa from St. Louis. During the first World War Soninke stokers and ship hands were hired on merchant ships going to French ports where the first communities of labor migrants were established (Adams, 1977:48-65).

The great surge of migration took place in the post World War II economic boom in Europe, starting in the late 1950s. Small groups of Soninke established in French cities became the essential links in the pattern of migration that evolved throughout the 60s and 70s. In this way, new migrants received help from kinsmen and friends who had preceded them in finding lodging and jobs. This opened the way to the process called chain migration (Duberson, 1975; Kane and Lericollais, 1975).

By the early 1960s residents of the Boundou started their own network of chain migration.

2.4.8.2. Migration from the project area

Long-distance labor migration is a major social and economic feature of the project area. The overall mean number of migrants per household in the project area is 1.5; mean length of stay away from home for migrants who have returned being 5.6 years. The range is quite wide, however; in our sample absences varied from a few weeks to several decades. The mean age of current migrants ranges from 27 to 30 years, according to the zone. The age pyramid in the project villages clearly shows that there are fewer men in their mid-twenties than would be the case without a constant outflow of men due to labor migration.

Among migrants the destination of choice is France with 80% of the migrants presently away being there, percent in Senegal and 9% in other African countries (for example, Gabon and the Ivory Coast).

Motives for migration, shown below, are clearly wage-employment oriented, whether for current or former migrants.

TABLE 2.10.

MOTIVES FOR MIGRATION

	Current Migrants	Former Migrants
Salaried Work	105	43
Trading	11	1
Schooling	4	-
Other	25	1

Migration is always temporary, done primarily to send money back, and leads to eventual return to the Boundou. The number of migrants who do not return seems to be very small. No one in the village that had migrants away for extended periods of time was willing to assume that they would not return home. The transition between the two worlds is difficult, but reintegration into the village of origin is the rule rather than the exception.

Since 1974 The French government has attempted to stop labor migrants from non-EEC countries, but they have had trouble stemming their flow. Our study found that a determined individual with connections in France can eventually find a way, so that most people expect migration will continue to be the main source of monetary income for the area.

2.4.8.3. Remittances and their uses

Remittances sent by migrants play a major role in the local economy. For example, during an eight-month period from December 1983 to August 1984, six villages in two of the project zones received a little over 9 million CFA Francs (about $22,500) in postal money orders. One village received over 4 million CFA Francs wile another received only 25,000 CFA Francs. The mode of remittances for the six villages was 1,700,000 CFA Francs. This is much superior to the value of sales of all agricultural products from these villages for the same period.

It is difficult to determine with certainty whether all the funds sent to a village are meant to be spent there. Funds sent to an homme de confiance in one village may be intended for another village. The project area, however, is generally a cohesive social unit, so it is fair to assume that even if remittances sent to one of the project villages are not all intended for it, the funds will stay with in the area served by the project.

Postal money orders are not the only way money is sent back. Some migrants send sums of money through friends who are returning on vacation or bring back cash themselves when they come on leave.

The uses of remittances fall into several categories. The most common is for household maintenance and to make up for any subsistance deficit. However, the migrant's primary personal objective is to use remittances to increase the size of his herd and acquire additional wives. This is followed by home construction, personal and family prestige, and community-oriented projects. Remittances also finance small shops run by migrants' wives or sisters; virtually all small shops in the villages are capitalized through remittances.

Remittances are also used to finance important collective efforts; in several villages, for instance, the digging of wells was financed through the participation of migrants. This kind of project may represent an investment of 600,000 to 1,500,000 CFA Francs divided among the 15 to 20 migrants from that village. Funds may also be used for other community projects such as building mosques. It should be noted, however, that in some villages the leading family has always assumed the responsibility for well construction and sees it as their right and obligation to continue. This kind of attitude does not encourage migrants who are not members of the leading family and caste to participate in community projects.

2.4.8.4. Returned migrants

Not all migrants have successful experiences. Some return after two or three years, having been unable to adjust to life in France or to find a job. Some have been unable to send money home, and return with very little to show for this sacrifice except a difficult experience.

Successful migrants, on the other hand, come back to manage larger households and herds. They play important roles and assume positions of authority and respect within the communities.

3. IMPACTS OF PROJECT INTERVENTIONS

Project interventions have necessarily been focussed on specific areas, but the assessment of their impacts is complicated by strong interactions, and the fact that some secondary benefits have turned out to be more substantial than gains from primarily intended purposes.

Technical interventions reviewed here include ponds, access roads and firebreaks, fire towers, the construction of the Mbaniou base, and the digging or repair of village wells. Extension-type interventions consisted mostly of livestock health services, functional literacy in Pulaar, home economics and child health monitoring by the Maison Familiale Rurale of Ndia, and the livestock marketing and supplemental feeding programs.

3.1. WATER CATCHMENT PONDS

The water catchment ponds built or provided by the project have had a definite impact. They retain water until January or February and are spread throughout the area so that livestock use range that would otherwise have been inaccessible or underutilized. Ponds also push back the time when men must draw water for their cattle. These benefits are well recognized by people in the area.

Benefits to livestock from ponds can be expressed in terms of water actually consumed by animals, and the length of time they were able to remain near the ponds. Livestock water consumption estimates were made for four ponds. Use was obviously greater during the camp (September-October) and dry seasons than during the rainy season, at any rate, as long as water lasted.

Unfortunately, even though all ponds filled at least once during the rainy season, they did not retain water for very long, and most of it was of no benefit to livestock. Figures 3.1. and 3.2. show typical volume versus time curves for typically "good" and "bad" ponds. In addition to the shortness of the span over which they retain water, one should note sharp decreases in volume when ponds are reasonably full. This can only be explained by infiltration losses since evaporation and livestock use were much lower. Overall, the total volume of infiltration amounted to at least 90% of collected water.

Table 3.1. shows the respective contribution of several factors leading to water disappearance.

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Figure 3.1. Pond with Worst Performance (Pond 10)

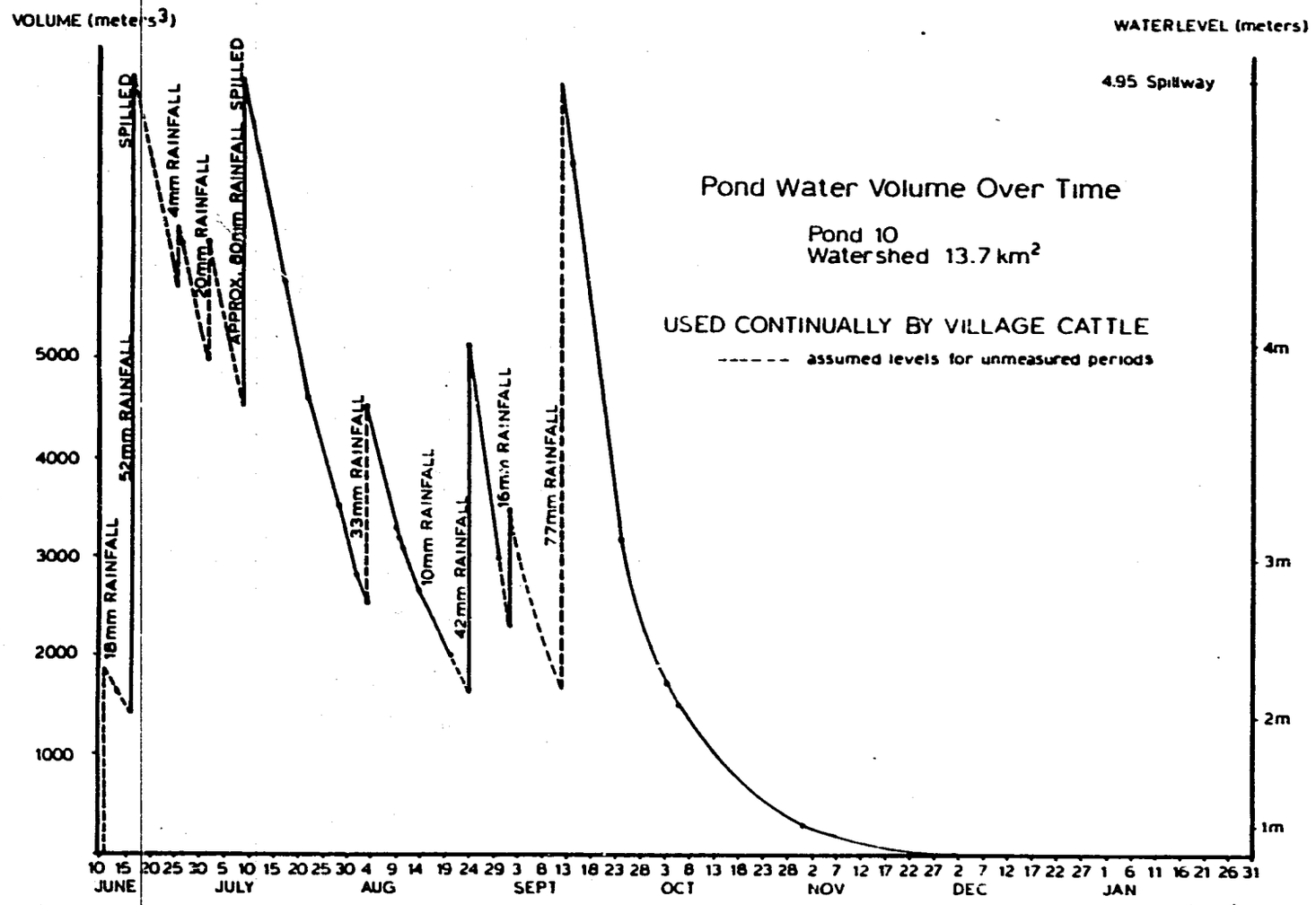

Figure 3.2. Pond with Best Performance (Pond 16)

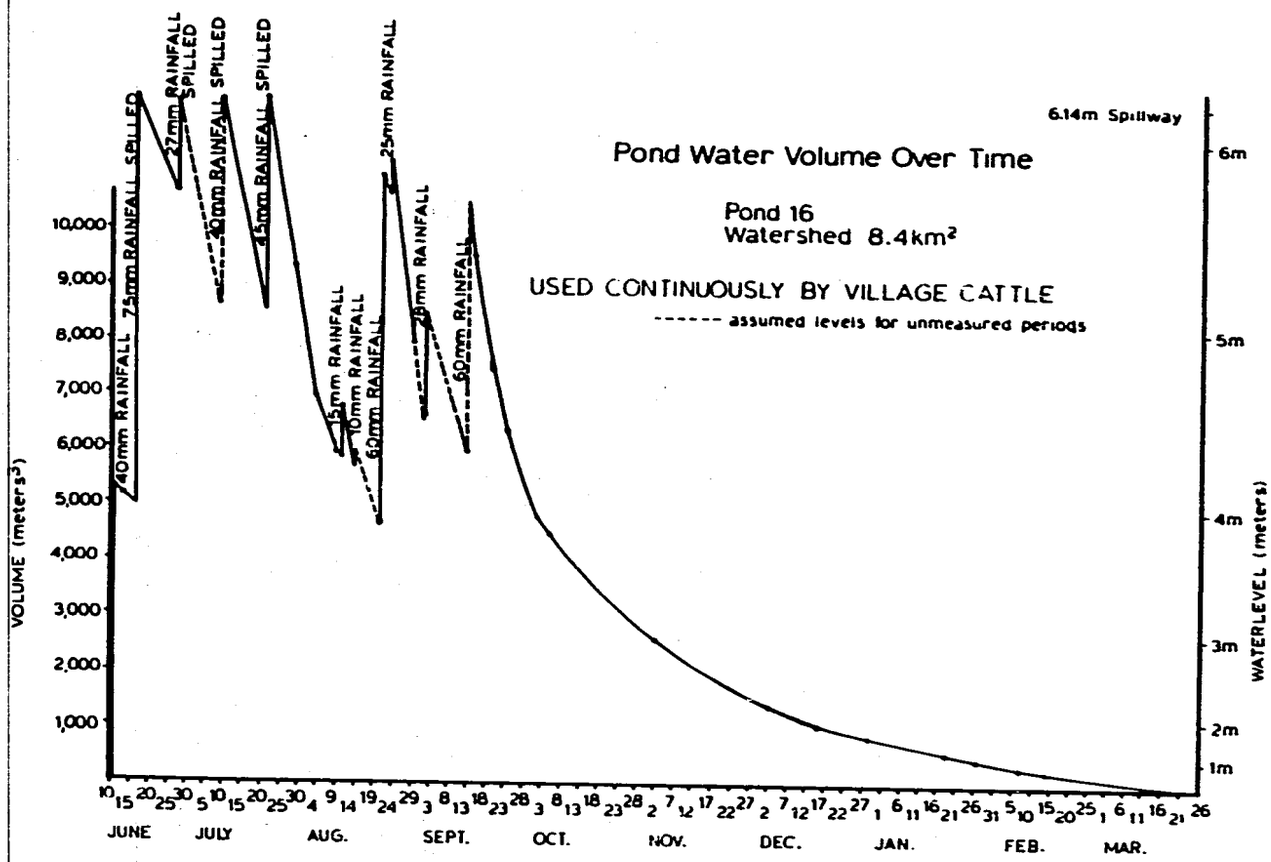

TABLE 3.1.

INFILTRATION, EVAPORATION AND LIVESTOCK CONSUMPTION, FOR THREE PONDS (in % of total by type)

Pond #	Infiltration	Evaporation	Livestock use
10	92.6	4.8	2.6
15	77	6	17
16[a]	67	11	22

NOTE: (a) Pond no. 16 was said to be the best by project staff and people in the area.

Even in the best case, water loss due to infiltration represented two-thirds of the total; the extent of water use by livestock for pond number 10 was only 2.6 percent of total. By contrast, the design documents had estimated combined water losses due to infiltration and evaporation at 35 percent.

Rates of sedimentation, on the other hand, were found acceptable, especially for ponds located on large watersheds since the ponds with highest levels of sedimentation were those receiving the least amount of water. Highly eroded sides suggest a major source of sediments was the embankments. A full pond with a downstream spoils pile appeared most efficient, because sediment tends to settle on the edges before reaching the center.

The particularly high rates of infiltration are directly linked to the geology of the Mbaniou Zone. The area is a flat plateau underlain by a layer of ironstone. This layer is typically shallow near the escarpment and away from the seasonal stream channels; in this case the overlying soil usually consists of gravelly sandy loam. Closer to the stream channels, however, the surface soil consists of sandy loam underlain by sandy clay loam.

The substrata of ponds were observed as part of the hydrological survey. Generally soils have an increasing clay content from top (about 15 percent clay) to bottom (approximately 20 percent clay), but these are ancient, highly leached soils, and their clays show little volume change upon wetting, so that they are highly permeable. Some of the pond bottoms are also bisected by ancient streambeds composed of a highly permeable medium-grain sand. In addition, pond design is such that the area of pond embankments is large relative to the area of the bottom. This means that even if sedimentation were to reduce infiltration through the bottoms, infiltration would still take place mostly through the sides.

There are a number of methods one can use to reduce infiltration. Most essentially consist of lining ponds with either plastic, asphalt, concrete or bentonite clay. An additive may also be mixed with the subsoil to reduce permeability. However, all of these methods are expensive, and require extensive redesign and annual maintenance, to protect the ponds from water erosion and cattle trampling. Mitigation of these problems would require a sizeable investment and substantial maintenance after construction. Nothing in the project's experience suggests that local populations have either the means or the incentive to take upon these tasks.

In conclusion, the benefits of the ponds is such that any gains on cattle up to mid-January, for example, have disappeared by the end of the dry season, and relief on denuded areas around villages is too brief to make an impact on the continuing process of degradation. Even if ponds retained water longer, one would have to build more in order to support cattle in a way consistent with the goal of insuring adequate forage resources (19 ponds have been completed, versus the 30 recommended in the original CID document). This is impractical for two main reasons: (a) there is a finite number of suitable sites, from the viewpoint of soils and drainways; and (b) the cost of building and maintaining that many ponds would be out of proportion with the value of gains in livestock and labor savings.

More thorough hydrologic and geotechnical studies are required before proceeding with this type of expensive structure. In this area, such studies would have revealed that most of the Mbaniou Zone has permeable subsoils unsuitable for pond construction. In addition to improvement of wells, the most practical alternative seems to be to deepen natural ponds found in the area. These retain water for longer periods of time than ponds built by the project because they have good clay bottoms, and are surrounded by vegetation which limits evaporation. Of course, this must be done with great care, so as not to damage the water retention capability of natural ponds.

3.2. ROADS AND FIREBREAKS

Roads were first built in the area (mostly in the Mbaniou Zone) to allow heavy construction equipment access to the pond sites. The term "roads" here refers to graded tracks usable at all times but the height of the rainy season. Access roads were widened and the network extended to provide a total of 185 kilometers of seven-meter wide firebreaks, suitable for project and private vehicles. In addition, three fire towers were built in the project's first phase, as part of the overall firefighting plan.

Comparisons of overall yearly rangeland burns in the mid-1970s (before construction of firebreaks), and of the present extent of burns, as well as ongoing observation during the project life, indicate that neither the extensive firefighting plan nor the firebreaks themselves have had a noticeable impact on annual burning. The fire towers have not been used, populations have not mobilized to fight fires -- except when cultivated fields and villages were actually threatened. The effectiveness of firebreaks has proved to be minimal, because of the orientation of prevailing winds, the narrowness of firebreaks, and very fast vegetation regrowth. All these problems have been explained in detail in previous work (inter alia, Legast, 1980), as well as in the Soils and Water Engineering, and Range Management reports. At the same time, the education effort designed to raise consciousness in the population's minds of the need for better bush fire management does not seem to have made much of an impact so far.

The basic problem is that total fire management in the area is technically possible only at costs entirely out of proportion with the benefits one would derive from protecting from fire vast expanses of little used rangeland. The only cost-effective way to deal with fires in vast low productivity areas is fire prevention rather than firefighting. However, this requires a difficult and long-term effort of dialogue and education with local populations. Fires will always occur in the project area, especially since occasional burning at the right time of year is beneficial to rangelands. Technical approaches designed to control fire, once started, appear doomed to failure.

This being said, it turns out that one of the most important aspects of project interventions is the impact that the establishment of this network of roads had on the area. Previously, this area of Senegal was one of the most isolated and inaccessible. The only means of communication available were sinuous little cart trails. Roads have allowed villages in the area to become integrated into the local administration. They are used by project staff for their regularly scheduled rounds. With better accessibility, traffic from government agencies and political parties has increased. Some private transporters have also started to penetrate the area. Villagers often speak of the new roads as an important improvement.

3.3. THE BASE AT MBANIOU

Many development professionals who have worked on and appraised livestock projects have come to the conclusion that excess physical infrastructure is the chief reason why almost none are financially or economically viable. The basic reasoning is that the very nature of the resources involved makes it extremely difficult to show tangible results of

interventions directly aimed at range and animals. The common reaction is to set up highly visible infrastructure (e.g., firebreaks, wells, corrals, fences, administrative buildings and so forth). In this particular case, however, the complete absence of any other infrastructure in the project area justifies such interventions as road building and the establishment of a technical base at Mbaniou, because of the many ancillary benefits from this infrastructure.

The construction of the Mbaniou base with its houses, classroom buildings, offices, storerooms, and garage, each provided with electricity and running water, has had this type of impact on the area. The establishment of such a base to permit the outposting of veterinary staff has been a success. Because of the precedent set at the base, veterinary staff were assigned to small villages throughout the project zone.

The base has exerted a very strong magnet effect by bringing other government projects. For instance, the base offers relatively comfortable housing, electricity five to six hours a day, and running water. The Ministry of Education has been able to send a teacher to the area, who started the first Francophone school in the zone. During the school year, 36 children were enrolled, coming from six neighboring villages; 12 of the students were girls.

The Bakel health project has also taken advantage of the physical facilities at the base and there is now medical personnel in the area for the first time.

3.4. LIVESTOCK EXTENSION SERVICES

3.4.1. Animal Health

Another successful intervention has been the provision of veterinary services in the project area. The outposting of ATEs (Agents Techniques d'Elevage) at the Mbaniou base and in area villages has made it possible to intervene almost immediately in response to outbreaks of contagious bovine diseases. On several such occasions the project was notified the same day; in the days that followed vaccine was brought in, and the threat of epidemic contained.

The fact that ATEs live in the villages and have a regular visiting schedule allows herders to consult with them, obtain advice and make them aware of any outbreaks of disease among their animals. It is our feeling that observed gains in morbidity and mortality of livestock are directly related to this particular approach of animal health extension services. One must emphasize, however, that this type of extension has definitely concentrated on cattle, at the expense of small ruminants. This reflects

conventional training and extension philosophies typical in West Africa, and the fact that small ruminants are most often managed by women.

3.4.2. Supplemental Feeding

To improve the condition of cattle, especially of cows which freshened before the rains, the project has relied on ATEs to encourage herders to buy and use cotton seed as a supplementary feed. The program was also intended to boost the quantity of milk available to the family by supplementing the ration of selected lactating animals. There is evidence that in larger villages with important concentrations of cattle, the supplemental feeding program has been adopted by some herd owners. Unfortunately, no priority in supplementary feeding seems to be given to lactating cows, as was suggested in extension meetings.

3.4.3. Livestock Marketing

The marketing program was established by project staff to give herders access to an additional marketing outlet, thereby promoting competition with other buyers, and hopefully maximizing the economic benefits derived by owners from animal sales. In the beginning, a contract was signed with SERAS, a public society in charge of livestock and meat marketing. Animals were bought on a live-weight basis, and transported to Dakar. Selling animals from the Boundou on the Dakar market was -- and remains -- a rational approach, since the price of meat at the retail level is higher in Dakar than anywhere else in Senegal. It turned out, however, that because of its costs and fees structure, SERAS could not really pay more on a live-weight basis than the prevailing rate among traditional buyers, and this approach was discontinued. It was then suggested that the project buy animals, transport them to Dakar with its own truck, and sell them to private traders on the capital's livestock market. However, it soon became apparent that this required a knowledge of the industry and professional connections -- in addition to some sharp management and business skills -- that no one on the project staff possessed. Nevertheless, continued improvement of project marketing activities should be sought. Currently, cattle are bought from herders and sold on the Bakel market, partly under pressure from local authorities who are having difficulties convincing private operators to butcher animals, given the official retail price of meat in the city. Supplying cattle to the city of Bakel therefore resembles more a public service than efforts to maximize the benefits derived by herders from their animals.

Our survey of inventory changes in livestock herds included prices received for animals sold; these were compared to baseline data collected eight years previously. For

cattle, comparisons of weighted average sales prices suggest an increase in prices received of about 30 percent; for goats, the increase is on the order of 20 percent. Baseline data on sheep prices are unfortunately not available, but considering the average 1984 sale price of sheep (over 13,000 CFA Francs), the increase in price received by local populations must have been much higher than for goats. Given that the project's marketing program handles a very small proportion of livestock sold in the area, one should not attribute to it any gains in prices received by owners for their stock.

As far as cattle are concerned, the option of helping organize shipments from the project area to more promising regional markets like Goudiry and Tambacounda must be seriously explored. Also worthy of additional involvement is the area of small ruminant marketing -- especially sheep. Project marketing activities dealing with sheep have excellent potential, especially as they may relate to the sharp annual rise in demand for Moslem holidays.

3.5. OTHER EXTENSION SERVICES

One must first recognize that general extension activities in the project's more recent phase (after the 1980 redesign) have taken on a relatively bold new orientation, and have been much more successful than anything attempted previously. Prior to 1980, the approach had been to provide livestock health extension through livestock agents working out of the city of Bakel, which meant that any visit to the project area turned into a minor expedition. Other extension services (sensitizing populations about project activities and objectives, education, home economics, etc.) were handled by Promotion Humaine agents, most of whom could not speak Pulaar, and had no technical knowledge of the local agropastoral system. In addition, technical staff in charge of livestock extension and Promotion Humaine agents answered to different administrations, and neither worked together nor coordinated their activities.

The project administration deserves very high marks for restructuring extension services along lines much more suitable to local conditions and more conducive to the establishment of a working rapport with the populations. In the first place, the technical and extension field staffs were moved to the Mbaniou base, located in the project zone. Secondly, livestock and other extension services are now handled by Pulaar-speaking agents either assigned to various villages, or operating out of the Mbaniou base. By working so much closer to project populations, extension staff have gained a greater degree of trust on the part of villagers, and a much better perception of day-to-day problems facing them.

3.5.1. Pulaar Literacy

One of the most successful project interventions has been the Pulaar literacy program. The project recruited and trained fluent Pulaar speakers to teach literacy in certain villages of the project area. The teachers, or AVEs (Agents Vulgarisateurs d'Elevage), are based in villages throughout the project area. From there, they have a regular schedule of classes in nearby communities. Villagers are expected to build a classroom for the students. Most are crudely built structures that provide shaded space to hold classes.

The classes are extremely well received with a high level of attendance. When visiting a village with a literacy program, one is struck by the amount of graffiti on the walls of houses, done either in chalk or charcoal. These are done by young students having learned to write, and possessed with the need to do so. Any vehicle arriving in the village covered with dust is soon used as a blackboard. Upon arrival, it is common to have young students proudly place in your hands scraps of paper with writing in Pulaar. In a compound where a new bench had been built, the fresh white logs had been almost entirely covered with writing in Pulaar.

The literacy classes, open to children as well as adults, are conducted around useful themes, for instance: how to recognize illness in a cow, ways a good herder should look after his cattle, or feces-borne diseases and village sanitation.

The Pulaar literacy program lasts three years. After the third and final year of classes, a Francophone school was opened in the Mbaniou Zone. The school was well attended, and students were well prepared undoubtedly because most had already attained a certain level of literacy in Pulaar.

3.5.2. Maison Familiale of Ndia

The village of Ndia hosts a Maison Familiale (rural family extension center), whose staff works in several villages of the Mbaniou Zone. They have been regularly monitoring the weight and growth of infants. With the help of the Maison Familiale, the villages of Ndia and Mbaniou have been able to obtain milling machines which are important labor savers for women. The Maison Familiale has also been the channel for the introduction of two technologies that may have some potential for lowering fuelwood consumption in the project zone. The first is a wood-burning stove made of adobe which may save 30 to 50 percent on cooking fuel. The few stoves installed in the area, however, have become disused. Perhaps pressure on fuel resources in the area does not appear to women sufficient to warrant a substantial change in cooking habits. It may also be that if the

wood gatherer and the cook are two different persons, the incentives to make the switch are quite uneven.

During the 1984 dry season, a medium-sized methane generator was installed at the Maison Familiale base in Ndia, and a smaller one in a project village. The larger generator supplied enough gas for a lamp and two stove outlets; the smaller one produced enough for a lamp and one stove outlet. The lamp was used every night and was greatly appreciated by villagers, but women did not use the stove outlets; they felt it did not give them the flexibility in flame size that they could obtain from traditional cooking methods.

3.6. CHANGE AND SOCIAL STRUCTURE

There is evidence of ongoing challenge to established social relations in the project area. This is causing friction both within, and in some cases, between villages. It is difficult to isolate the principal agents of this change or to determine their order of importance; however, migration plays a major role and along with the project itself is a chief agent of change. Because of its institutional nature and of services it brings to the area, the project has tended to crystallize conflict that would have otherwise remained muted.

The changes attributable to migration have occurred both at the individual and at the community levels. In some villages, for instance, slave and artisanal caste households have been able to improve their economic position considerably through labor migration. All castes are likely to migrate since social status does not appear to be a determinant of labor migration. Migrants from lower and upper caste households have equal chances to succeed, and some lower caste households have done very well for themselves. This raises mild but unquestionable challenges to traditional social order.

Some of the project programs have led to direct challenges of the established social order. A good example has been the project's introduction of functional literacy classes in Pulaar. The curriculum of the Pulaar program lasted three years, with classes being open to all. In the Mbaniou Zone, 1983 marked the end of the first literacy program. To continue the program, project staff held a test to select the best students in each of the villages for training as teachers. The selection of former students was done essentially on the basis of merit. In one village the best student was a young man from a slave caste household. He was given the responsibility for teaching classes in his home village and in several surrounding ones. Of course, this meant he would be teaching religious and chieftainship caste children as well as those from slave and artisanal castes. The upper caste family that gives the village its chief objected to this and asked that an upper caste

student be made the teacher. When the project staff refused this request, the chief notified them that the village would not participate in the continuing literacy program since it meant that upper caste children were to be taught by a slave caste youth.

Another example of friction between castes as a result of project intervention occurred in the same village. The research and evaluation team gave malaria pills to participating villages. These were presented in a public forum, and it was stated that they were intended for the village as a whole. In this particular village the pills were never allocated throughout, but were all used within the chief's family. When a second such gift was being made, the project representative was approached quietly by a lower caste member requesting that the project give another box of pills for the lower caste households, since they had not been able to share in the first allotment of pills.

The stronghold of the traditional social and historical order is not only evident within villages; it plays an important role in relations between settlements. This became obvious when an attempt was made to group villages together to work on demonstration plots using various methods to prevent erosion. One village scheduled to participate considered itself historically and socially superior to the others and refused to take part in the collective effort. They felt that the effort should have been done on their terms, and that they should not have been asked to participate as equals with villages of lower status.

These are some of the most obvious manifestations of conflict precipitated by project interventions. However, in most cases conflict was not as obviously manifested. The village chief can play an important role in minimizing conflict within the village. In the project area it appears that villages with weak or unresolved leadership have more open conflict problems.

Leadership in the project villages is assumed by the eldest male survivor of the founder or founders of the village. The line of succession is from eldest brother to youngest brother and then on to the eldest son of the eldest brother. The leadership of the chief is an expression of the consensus opinion based on the village's leading family and its elders. If the leading family has not agreed on its leadership, or if the leadership is weak, support for major issues is more difficult to establish. Conflict can be an indication that the leadership is not consolidated or that there is some dissention between the senior men of the founding families about the abilities of the present chief. In villages where the chief is a strong leader and takes time to look after problems, neither caste conflict nor disputes between households are too pronounced. In most villages of the project zone the leadership is well in-hand.

3.7. RANGE USE, IMPROVEMENTS, AND PRELIMINARY MANAGEMENT PLAN

3.7.1. Use of Range Resources by Livestock and People

Part of the data collected for the design of a range management plan included surveys on spatial patterns of daily grazing by large and small ruminants, and on the composition of cattle diet.

Cattle tend to use the same general areas for many weeks, although daily grazing in the rainy season is centripetal: livestock move closer to the villages as the season advances. In the early to mid-rainy season, livestock have to walk relatively far in order to consume their full. In the transitional period between the rainy and dry seasons, they remain around villages to graze crop residues. By the mid-dry season, distances travelled for feed are longest, but near the end of the dry season slightly shorter distances are required because the trees start to get new buds, a major source of feed for all livestock.

Small ruminants graze closer to the villages, and are watered around mid-day by women. Flocks may be accompanied by a herder at the end of the dry season when forage becomes scarce; the herder follows the flock and chops down tree leaves and pods for the animals.

People also rely on range resources for a number of economically important uses. The Bakel market offers a diverse supply of products (e.g., gum arabic, medicinal plants, construction material and fuelwood).

3.7.2. Important Features of the Livestock Management System

Certain aspects of livestock management are not consistent with higher levels of range and livestock productivity. In addition to customs, people behave as they do on the basis of a given rationale. We recognize that new management practices can only issue from a combination of educational efforts and a change in the social and economic environment. Nevertheless, the management features currently representing some key constraints are outlined below.

The paramount feature is the lack of herding of livestock; cattle are herded only when at "camp," or during a long transhumance. Although professional herders are most often hired for this, one must note that they also help with crops during the rainy season. Herding is practiced more often in the Senegal Basin area, but even there, only as a last resort. Herding is clearly not an attractive proposition to the people; however, any improvement in range and livestock would necessarily require more careful supervision of herds.

The only other significant labor expenditure for livestock is watering, especially during the dry season. The order according to which herds are watered is established at village meetings and naturally reflects the community's hierarchal power structure (the order doesn't change over time).

During the dry season cattle are staked overnight over fields, the location being changed about every two weeks. However, this prevents manure from being trampled and pulverized, so that benefits to the soils are diminished or delayed, even when the same fields are manured year after year. Other groups, south of the project zone, tend to keep cattle over one spot throughout the season so that they pulverize most of the manure, which is then spread over the fields by the family.

3.7.3. Range Improvement Program

The range improvement program had two major objectives. The first was to find ways to revegetate denuded areas, and to recommend degradation prevention methods. The second was to evaluate the effects of drought and to study the potential for the introduction of new forage species.

3.7.3.1. Revegetation of denuded areas

The extent of land degradation in the project area has been referred to in various parts in the Synthesis and in the other individual reports. One can classify denuded areas into four main types. The first type may be called "sandy mounds;" these reflect the initial process of soil erosion, created by trampling, loosening the top soil layer, and compacting what is underneath. Rain and wind then erode the finer soil particles on the surface. The affected area thus gives the appearance of sandy mounds.

The second type of denudation is labelled "cemented pavement;" all the grasses on the sandy mounds have been grazed and the sands eroded, leaving an almost smooth, very compacted soil surface. Because of the compaction, there is limited water infiltration, and trees and shrubs cannot survive. Only a few short, hardy grasses grow there, along with some perennial bulbous plants. Where there are small cracks in the soil, water erosion may take hold and create eroded gullies, which is the third type of denuded area. The fourth, and most extreme case of denudation is labelled "moonscape," and constitutes an advanced stage of the gully formation process. Here erosion exposes the subsoil (C-horizon) in the gully formation. The remaining soil is alkaline and cannot support any vegetation. It was felt that these areas were too far advanced in the erosion process and no attempts were made to revegetate them.

Any attempt at revegetating denuded areas (except moonscapes, which are in a state of erosion beyond revegetation) must combine modification of livestock management practices to prevent further degradation by animals, and active revegetation. Five techniques were tested for the revegetation of denuded areas in the Gambia basin area.

3.7.3.2. Five experimental techniques for revegetation

3.7.3.2.1. Fencing. This was done using local techniques and materials; the problem, of course, is that this requires cutting new tree branches! Fencing is rather time-consuming (20 men/day to build about 100 meters of fence); and the fences must be replaced at least once a year. Fencing by itself was found to be beneficial on sandy mound type areas, but not effective on the more seriously denuded areas.

3.7.3.2.2. Dead-wood dikes. These were placed perpendicular to the slope, retaining both soil and seeds (mostly for grasses in the first year of succession). The theory is that after the first year, more herbaceous plants establish themselves, and eventually the soil's infiltration rate increases enough to allow the growth of trees and shrubs. The results from this experiment were encouraging, especially on cemented and gully-type denuded areas, however, this technique takes years to have a full impact.

3.7.3.2.3. Planting trees. Retrogression studies have shown that *Acacia senegal* appears to outlast other trees on degraded soils. Seedlings were therefore planted on the sites, along with *Parkinsonia aculeata*. In general, *Acacia sen.* performed better, but the lack of herbaceous cover on the planting sites minimized infiltration of water toward the roots and cast serious doubts on the trees' chance to survive much longer.

3.7.3.2.4. Ripping with draft animals. This technique was applied only to cemented soils, with a pair of oxen hitched to a local disk. Even just after a rain, the soil was very hard and the blade did not go deeper than 10 cm. The first-year effects were remarkable, but by the second year the vegetation cover receded, unless the soil was ripped again. In addition, disking may promote further soil erosion.

3.7.3.2.5. Ripping with a bulldozer. This was done on another cemented area, up to depths of 50 cm. Rip lines were seeded with a variety of species at a rate of 3 Kg/ha. The resulting overall density of herbaceous plants was low however. In addition, this technique involves high costs, and equipment available only through government agencies.

The best approach for revegetation appears to be a combination of all techniques tested. The most effective combination would include ripping the soil, planting *Acacia senegal* in rip lines every five meters, and placing dead wood dikes every five meters downslope from the trees. This would encourage at the same time a rejuvenation of the soil, and of the herbaceous and woody layers. However, there are two main problems. In

the first place, villagers are obviously aware of the overall problem of expanding degradation, but do not seem willing either to link it to overgrazing or to treat it as a crisis situation. Secondly, the extent of denudation is such that even if villagers were willing to take on the task of soil regeneration, their own resources are much too limited for effective action. Any effective program of degradation control would thus require a combination of education at the village level, to enlist the essential cooperation of affected populations, and a sufficient committment on the part of the government to allocate the necessary resources.

3.7.3.3. Introduction of new forage species

Since the 1968-72 Sahelian drought pattern started, various researchers have observed profound changes in the species composition of rangelands. The range manager's own work in the project area and other local or related sources suggest two major observations: (a) the northern limit of Bombax costatum, a tall tree of the Sudanian region, has progressively moved south; and (b) there has been a marked reduction in the density and spatial extent of perennial grasses and forbs.

The purpose of the forage trials program was to test the adaptability of exotic, drought tolerant perennial grasses and legumes. In 1983 and 1984 a total of 89 different forage species and varieties were planted in the Mbaniou Zone, including trees, shrubs, herbaceous species, and a few plants suitable for both human and animal consumption.

For trees and shrubs, Acacia senegal and Parkinsonia aculeata performed particularly well, along with Leucaena leucocephala and Cajanus cajan. Two of the perennial grasses, Cenchrus ciliaris and Panicum antidotale appear to be able to survive in the area, especially the Cenchrus spp.. Cenchrus ciliaris and Macroptilium atropurpureum (Siratro) performed well on the degraded sites that had been ripped; Siratro had the added benefit of being a trailing plant that can provide good cover to the soil.

The two millet and the perennial soybean tested performed much less well than local crops. However, people seemed to appreciate the niébé (Vigna unguiculata), in association with sorghum in their fields.

3.7.3.4. Preliminary range management plan

The preliminary Range Management Plan (RMP) is a synthesis of research activities and discussions with project personnel and villagers. The purpose of this Plan is to provide guidelines for the management of livestock range and water resources by the people of the project zone. The guidelines are primarily aimed at preventing further degradation of the rangeland, and at improving the productivity of the livestock. The role of the project

should be to extend the Plan to the people and to assist with financial and technical resources wherever necessary. The Plan incorporates three organizational levels that currently exist in the project zone: herders, villages and pastoral units.

At the herder level, the Plan concentrates on providing guidelines to improve the use of the rangelands. The implementation of the Range Management Plan as a whole presupposes close year-round supervision of herds.

In order to prevent the concentration of animals around the villages, the RMP calls for a stratification of the village herd into a "bush herd" and a "milk herd." The milk herd is to be composed of the milking cows and their calves, and a few draft oxen. These animals, along with the equines and small ruminants, would be kept permanently at the village. An approximate 5 km radius around the village would be reserved exclusively for them. They would water at nearby natural ponds or the well, and would receive supplemental feed and minerals.

The bush herd would be composed of the remainder of the cattle (heifers, pregnant cows, bulls, etc.) and they would be herded at camps. Whenever a pregnant cow dropped her calf, she would be returned to the village, and dry cows and their calves would be taken to the camps. Otherwise the bush herd would remain on the range all year, moving from one pasture to the next.

The idea of stratifying the herds is not new. Certain pastoral groups in Africa such as the Dinka of the Sudan have been practicing it for thousands of years. But it is a new idea for settled agropastoral groups such as the Toucouleur. However, it is an idea that is not too much beyond the existing husbandry system. Already the animals are herded to distant camps even though it is only for the protection of fields. In addition, if the owner is forced to send his cattle on transhumance to Mali because of the lack of water in the village well, he will try to keep a few milking cows for the household's needs. Finally, the herd stratification strategy relies on a relatively cheap resource: the herder. Fencing off the pastures into grazing blocks would achieve the same results, but fences are quite beyond the people's financial resources.

One constraint to the success of the stratification strategy is the fact that the water catchment basins built by the project do not retain water throughout the dry season. Therefore, the bush herd would be forced to return to the village well when the water-points dried up, but they would be herded out again with the first rains of the season. Therefore, they would be spending at least 6-8 months of the year away from the village. It is expected that this reduction in the grazing pressure around the villages would help to prevent further degradation of the soil. In addition, it is expected that the greater forage availability for both the bush and milk herds, as well as a decrease in the

distance that they have to walk everyday, would result in significant increases in live-weight and milk production.

Other programs at the village level should include certain improvements in the cultivation/livestock interaction (discussed in Chapter 3 of the Range Management Report) such as better manure utilization techniques, fallow-crop rotation systems, and better maintenance of fences around the fields.

Finally, the revegetation of denuded areas should be organized at the village level since 90% of the denuded areas are in the radius of individual villages. The project should encourage the formation of working parties, village nurseries and seed multiplication plots. The women should also be included in this program.

The pastoral units (UP) are the only institution that can be used to manage the more communal, extravillage resources, such as water-points and firebreaks. One cannot expect the project to continue to manage them, nor can one expect the government to take over the responsibility.

Therefore, the project must concentrate its efforts on establishing the institutional legitimacy and framework of the UPs. In addition the UPs must be assisted by the project so that they can take over the responsibilities of organizing communal work. At the moment, the most important communal actions that could be done are the water development strategy (discussed in Chapter 4.1. of the Range Management Report), the cleaning of firebreaks and control of bush fires, and the improvement of rangelands through reseeding with perennial grasses and legumes.

Once the government has established the UPs legitimacy of land tenure, the project can begin to emphasize the land use implications. The concept of "grazing or watering permits" and the fact that these permits apply to the use of their range by both neighboring UPs and nomads, must be discussed with the people. The two hurdles to implementing a permit system (social inacceptability, and the lack of physical means of supervision and control) should also be discussed, but will have a better chance of resolution if the rural communities are established and if the Sylvo-Pastoral Code incorporates the concept of permits.

In conclusion, the RMP proposes a series of programs aimed at three main organizational levels: the herder/livestock owner, the village, and the pastoral unit. The project's role should be to encourage the adoption of certain improvements in the traditional animal husbandry and range exploitation system, the details of which must be filled in by collaboration with the people. The adoption of all aspects of the RMP cannot be expected very soon. However, the RMP's simplicity, and the fact that the programs at each level can be implemented independently of each other, suggest that the failure of one aspect of the Plan would not necessarily jeopardize any other aspect.

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Range Management

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Contract No. 685-0202-C-00-2137-00

February 1985

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EASTERN SENEGAL RANGE AND LIVESTOCK DEVELOPMENT PROJECT

RANGE MANAGEMENT REPORT

by

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Range Manager

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February 1985

55

Published by

Center for Research on Economic Development
307 Lorch Hall
University of Michigan
Ann Arbor, Michigan 48109-1220 U.S.A.

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ACKNOWLEDGEMENTS

The author would like to thank the following for their contributions: Dr. J. Dickey (SDPT/USAID), Dr. Valenza (LNERV/Senegal), and Dr. H. Breman (PPS Project/Mali) for their valuable insights into the range and livestock systems; Dr. H. Gillet and the staff at the Herbarium of the Museum National Historique Naturelle in Paris, for the verification of the identity of the plants collected in the project area; Dr. Roberge (ISRA/Senegal), Dr. Bailly (CNRF/Senegal), Dr. H. Hulet (ILCA/Mali), Dr. Sgaravatti (FAO/Italy) and Dr. J. Gritzner (BOSTID/USA) for the timely supply of experimental forage seeds; Mrs. K. Dieng (ORANA/Senegal), Dr. Guerin (LNERV/Senegal) and Dr. M. Arborio (Institut Pasteur/Senegal) for their interest and assistance in the laboratory analysis of milk, forage and water samples, respectively.

The excellent support provided by the Senegalese Project Director, Dr. Abdoulaye B. Niang, during the two years of our fieldwork was greatly appreciated. Without this support, and without the constructive and friendly relations between the CRED team and the Senegalese staff, none of this would have been possible. The USAID/Dakar Project Officer, Mr. Larry Harms, and his staff, smoothed over many administrative tangles.

The backing provided by CRED Project Director Dr. Edgar Ariza-Nino, and Dr. Henri Josserand, and their visits to the project helped us to stay on course. The assistance of the CRED support staff was indispensible and greatly appreciated. The author thanks Dr. Robert Bement for taking the time, and the trouble, to visit the project and for providing useful suggestions. Many thanks also go to Patrick Thomas and Allen Clark and their families for helping to make an excellent team, and making life that much more enjoyable in Bakel.

Finally, the author thanks Oumar Ndom and Mohammadou Ba of the village of Toulekedi for their cheerful assistance in the often laborious range research tasks, and for being excellent models for the other young people in their village.

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I. INTRODUCTION

The overall goal of the Eastern Senegal Range and Livestock Project, as stated in the project paper amendment of 1980 is to introduce a package of technological and managerial changes in the traditional livestock production system of the Bakel area that would have potentially replicable results for increasing the productive capacity of the Senegalese National Livestock Sector.

The Bakel project area covers approximately 250,000 hectares within the 500-600 mm annual rainfall isohyet. It is divided into two fairly distinct ecological zones, the eastern part within the Senegal River Basin and the western part within the Gambia River Basin.

The majority of the population are sedentary Toucouleur agropastoralists. Millet and sorghum are the main cereal crops, which are grown under rainfed conditions on the slopes and beds of fertile drainage ways. Sheep, goats and cattle are the main form of livestock produced. The rangelands in the project area are one of the highest potential areas in Senegal as a whole, but are not utilized effectively because of the lack of adequately distributed water sources.

The Eastern Senegal Range and Livestock Project was designed to specifically introduce surface water catchment ponds in strategic locations across the range area. In addition, the project provided for the construction of firebreaks, to control bush fires.

In the period between 1978 and 1982, certain interventions have been realized. With the assistance of various short-term and long-term consultants, 12 water collection ponds had been constructed as well as 185 km of 7 meter-wide firebreaks. The contribution of the technical consultants included the original project design document, a hydrological report on the design and implementation of surface water collection ponds, a range evaluation report, and a proposal for fire prevention and control.

Veterinary services and vaccination campaigns by the project staff are a regular feature of the project. An alphabetization program has been successfully implemented in the project area and a network of extension agents have been placed in the villages. A preliminary socioeconomic survey of the Mbaniou Zone in the project area had also been carried out. Since 1982, the two new zones of Sinthiou Fissa and Ololdou have been added to the project area.

The Center for Research on Economic Development (CRED) at the University of Michigan, was contracted in 1982 to provide a long-term technical assistance team to the project. The team was composed of a soils/water engineer, a socioeconomist, and a range manager.

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This is the second in a four-part report by the team and CRED, and describes the activities of the range manager during the period of October 1982 to October 1984. The other parts include the Synthesis Report, the Soils/Water Engineering Report, and the Socioeconomic Study.

The range manager has been responsible for: a) an inventory of range resources and determination of the forage production and potential of the rangelands; b) an evaluation of the impact of water catchment ponds and fire control activities by the project; and c) the design and development of a Range Management Plan for the project area.

This report is organized according to the following headings:

Chapter 2: Summary of Conclusions and Recommendations
Chapter 3: Report on the Research Activities
Chapter 4: Evaluation of Project Activities
Chapter 5: Preliminary Range Management Plan

2. SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

- Maintain the present stocking levels until the three constraints of water, bush fires, and denuded lands are resolved.
- The water development strategy for the Gambia Basin area should be based on improving existing water catchment basins.
- The water development strategy for the Senegal Basin area should be initiated with research on alternative water-harvesting techniques.
- Continue the antifire themes of the functional literacy program.
- Continue building new firebreaks, only if an appropriate way is found to clean them using local resources.
- Encourage year-round herding of livestock by the villagers.
- Assist villages in the revegetation of denuded lands.
- Restrict livestock from the floodplains and streambed range types in the wet season.
- Continue the long-term ecological monitoring of the rangelands.
- Continue the research on range productivity.
- Continue the research on fuelwood use by villages, in order to develop a village reforestation program.
- Encourage village-based nurseries and seed multiplication plots to provide forage legumes and trees for the reforestation program.
- Continue research on the dissemination of perennial, drought-resistant grasses onto rangelands.
- Encourage a more effective supplementation program for milking cows.
- Continue the monitoring of livestock productivity.
- Encourage a better utilization of manure on farmlands.
- Concentrate the commercialization program on the northern Ololdou Zone.
- Expand the staff and resources of the functional literacy program and extension services.
- Concentrate on building the institutional capacity of the pastoral units.
- Implement the Range Management Plan discussed in the report.

The natural resources within the project zone are influenced by the geological feature of the continental shelf. This shelf divides the zone into two very separate areas, each with its own distinct soil, vegetation and geological formations and potentials. These differences necessitate slightly different development strategies for either side.

The Toucouleur of the project zone maintain a very diverse portfolio of livestock and crops designed to meet various needs. Cattle are kept mainly for their milk, as a source of wealth and as recurring income (reproduction). Small ruminants and poultry are raised primarily for their meat and as gifts or for other cultural transactions. Horses and donkeys are kept as draft animals. However, the management of these livestock traditionally has not required much investment (whether capital or labor). The only substantial labor requirement is during the times that livestock are watered at the village well. Herding does not require much labor since the animals are usually herded for less than two months of the year. Therefore, compared to the cultivation system, very little time, labor and economic resources are spent on maintaining and exploiting the livestock.

This lack of control over the livestock is a major cause of degradation of the rangelands in the project zone. Various simple changes in the management system are proposed in the Range Management Plan that could help prevent further environmental degradation. Contour plowing of steep areas on the fields, a more efficient fallow/crop rotation cycle, and a better crop residue/manure exchange between cattle and the fields, would help to increase the productivity of the cultivated lands.

It is recommended that two monitoring programs be established by the project on the productivity of the livestock. The first is a live-weight monitoring system and the second, a milk quantity/quality monitoring system. Both systems would follow on data gathered thus far, and would be used for ongoing evaluation and feedback on the project's impacts (especially the supplementation and commercialization programs).

The studies done on the range productivity to date show that the rangelands are composed of an annual herbaceous community with a good mixture of grasses and native legumes. They also support an important woody stratum that has many palatable species. The range as a whole is primarily suited to a diversified industry of small and large ruminants.

However, the rainfall patterns result in a tremendous variability in the availability of the annual biomass. This variability is apparent not only in time (eg., between years), but also in space (from one spot to the next). The lack of control over these factors means that the management strategy has to remain flexible and acutely aware of small changes in the productivity of the land.

The forage on the rangeland is of a fairly high quality in the wet season, but it quickly deteriorates as the dry season advances. The presence of nondecidious trees during the dry season is a helpful boost to the livestock diet. However, studies suggest that the livestock suffer from certain mineral deficiencies. Supplementation of the diet of livestock would probably result in gains in milk, live-weight and work-energy of livestock.

Bush fires devastate almost 50% of the rangelands every year. Not only does this mean less forage in the dry season, but studies also suggest that yearly bush fires tend to result in an increase of less desirable bushes and a decrease of herbaceous legumes. In terms of the ecology and the livestock industry, this is not a desirable trend. However, fires at regular intervals (eg., every 3-5 years) would probably be beneficial. But to implement these beneficial fires, more control must be exerted over people and pastures.

Studies of the community productivity suggest that if certain range types (especially floodplains and streambeds) were not used during the wet season, then their overall herbaceous productivity and their theoretical stocking potential would increase.

Studies also show that denuded land areas have been increasing at an average rate of 5.6 ha per year per village since 1953. The main causal agent is the lack of control over the livestock and overgrazing, especially during the wet season. Therefore solutions must include, on the one hand, revegetation of areas already denuded, and on the other, prevention of further degradation by proper management of livestock.

There are various techniques for restoring denuded lands. Each of the five techniques tested has certain technical and economic advantages which make them appropriate for different soil and vegetation characteristics. However, the extent of the denudation is already so vast, that the people cannot be expected to revegetate it all by themselves, no matter what technique they use. The project must take a more active role in motivating and assisting the people in the task.

The recent droughts have taken their toll on the rangelands. The forage trials showed that a few exotic, drought-tolerant, perennial grasses and legumes appear to be adaptable to the project zone. More work needs to be done on finding an easy, appropriate way of disseminating these plants into the pastures. Other herbs and trees appear to be suitable for the reseeding of denuded areas.

A few exotic plants were found to be adaptable to conditions around the village. These include forage trees that could be planted inside the village compound, new bean crops that could be planted in association with the local sorghum or millet, and some legume plants that could be planted as a soil fertility-building fallow/crop. It is

recommended that the project encourage village-based nurseries and seed multiplication plots to supply their seed and seedling needs.

The range inventory is a useful tool for overall resource planning. This particular inventory was also designed to allow long-term ecological monitoring. The point center quarter and frequency-biomass methods of measuring the vegetation are fast and require very few tools, none of which are sophisticated. Given the problems of environmental degradation, it is strongly recommended that the project (or another research institution) initiate a long-term ecological monitoring program that would allow a yearly collection of data from the inventory sites. It is recommended that the woody species be monitored at least every five years, and that the herbaceous species, and the rainfall, be monitored every year.

In order to verify and complete the data on range productivity, following research activities are recommended:

- Continuation of yearly biomass studies on inventory sites
- Research on the productivity of the woody species
- Continuation of research on the ecological impacts of bush fires
- Continuation of the monitoring of the succession and retrogression study sites
- Grazing trials on the two important range types (both of the floodplains), or if resources are limited, continuation of the clipping studies

Research on the patterns of range use by livestock show that it is primarily a function of the availability of water. Water determines the seasonal movements of livestock, as well as the use of distant pastures. However, the availability of specific forage species which is determined by the range type, the season, and the incidence of fire, is also a very important determinant of range use. Therefore, the allocation of water-points in the future should also consider the range types and the availability of forage.

People use the rangelands in many different ways, and the Bakel market offers a diverse supply of rangeland products, most of which are locally gathered or processed. It is recommended that a survey be conducted to measure the quantity of wood being used by the Bakel residents as well as other villages for construction and fuelwood. This survey would be used to develop a reforestation program in the project zone.

Theoretical calculations of the actual stocking capacities of rangelands in the project zone show that given the present conditions of inadequate water distribution, up to 50% yearly loss in biomass due to bush fires, and 10% of the land surface being denuded, the

estimated actual stocking rate (i.e., the number of animals actually on the range) is very close to the estimated stocking capacity of the dry season in a bad (drought) year. This stocking capacity may be increased in good years. However, given that for the past ten years there have been more bad than good years, the stocking rate should not be allowed to increase beyond its present level.

It is recommended that until the present resource constraints are resolved, the stocking rate be kept below a ceiling of 10,000 UBT/dry season in the Gambia Basin area, and 11,000 UBT/dry season in the Senegal Basin area. If, however, bush fires could be controlled, denuded areas revegetated, a decentralized system of permanent water-points developed, and livestock be herded year-round, then the stocking capacity could probably increase by 300%.

The water catchment ponds built in the Gambia Basin area have only partially fulfilled their main objectives. However, they are potentially very appropriate to the range situation and the system of livestock husbandry in the area. It is recommended that the water development strategy for the Gambia Basin area incorporate two important aspects. The first is further investment in improvement of the ponds (to reduce infiltration and evaporation rates). The second is the organization of a water development committee in each pastoral unit who would be responsible for the use, improvement and maintenance of the ponds.

The water development strategy for the Senegal Basin area must recognize the different constraints facing the area. It is recommended that further studies on alternative water-point schemes be done, especially on other water-harvesting techniques. It is also recommended that a water development committee be organized in each pastoral unit of the Senegal Basin area.

The efforts of the Project to date in controlling bush fires have not been very successful. It is recommended that the project should concentrate on attacking the causes of bush fires by continuing the Extension Program's antifire themes, and by devising appropriate ways to gather honey or hunt wild animals that would not require smoke.

In the meantime, the extent of bush fires is so vast that even if the fire brigades were efficiently organized, they could not physically reach all parts of the range in time. On the other hand, a more efficient system of firebreaks would probably contain most of the fires. However, more firebreaks will be a solution only if a way is found to clean the lanes using local resources. The project should put some effort into designing an appropriate firebreak cleaning method.

The commercialization program, after a very slow start, may be potentially useful in helping the people benefit from the sale of their livestock. This program should concentrate its efforts in the northern Ololdou Zone so as to help destock the excess livestock from the area. It should also put a new emphasis on marketing small ruminants.

The veterinary services of the project have perhaps been too successful. In order to prevent an imbalance of livestock numbers and range resources in the immediate future, the project should concentrate more resources into improving rangelands.

To date the supplemental feed program has shown that some people are willing to buy supplemental feed for their animals. The project should emphasize the supplementation of milking cows rather than all animals. In addition the possibility of cooperating with the SAED Irrigated Rice Project in order to obtain rice crop residue should be contemplated.

The project's social services program has been active in testing, among other things, various appropriate technologies, the most promising of which are the biogas generators. The project should incorporate this technology into a larger research/extension program.

The extension services and the functional literacy program are one of the most important and successful programs of the project. Many of the proposals contained in this and other reports would not be feasible without such an extension "backbone." It is recommended that the services should be expanded, not only in terms of the level of its staff and resources, but also in terms of diversifying into other extension topics, such as herder education, rangeland hydrology, and new organizational/managerial concepts.

The pastoral units (UP) have the potential to be a useful institutional framework for the management of communal resources. However after three years they still exist only on paper. The project should radically change its existing program and adopt a more active, field-oriented, institution-building strategy. It should emphasize more discussions with the people on the principles and praxis of the UPs, and should organize communal work situations. Finally, the project should try to encourage the government to draft and implement the Rural Communities and Sylvo-Pastoral Codes which would provide the legal justification for the existence of the UPs.

The main purpose of the Preliminary Range Management Plan (RMP) is to provide guidelines on the management of range resources by the people of the project area, with the immediate objectives of preventing (and controlling) rangeland degradation, and improving the productivity of livestock.

The RMP proposes a series of programs aimed at three different organizational levels. At the herder/livestock owner level, the RMP proposes a major extension-education effort designed at encouraging an institution of permanent herding of livestock. The RMP also proposes a "professional herder education course" that would

extend the range research results, and would train the herders to use the "early warning system" for evaluating the condition of the range.

At the village level, the RMP calls for the introduction of a "herd stratification" plan that would divide the household's cattle into an extensive "bush herd" which would remain permanently on the range, and an intensive "milk herd" which would remain permanently at the village. This partial destocking of the areas around the village is expected to prevent further degradation, and improve the productivity of the livestock. The RMP also calls for a program in revegetation of denuded areas at the village level.

At the pastoral unit level, the RMP calls for the organization of communal work parties on cleaning firebreaks, reseeding some pastures with perennial grasses, and improving/maintaining water catchment ponds through the Water Development Committee.

The RMP's apparent simplicity stems from the fact that it tries to take the traditional management system one step further. The programs at each level (herder, village, UP) can be implemented independently of each other, which suggests that the failure of one aspect of the plan does not necessarily jeopardize any other aspect. The task of the project should be one of being sensitive to people's reactions, and should take each step forward at its own pace.

3. REPORT ON THE RESEARCH ACTIVITIES

When the range manager arrived on the project, there was a distinct lack of systematic data on the rangelands. Previous technicians had concentrated on some reforestation experiments or had looked at the role of trees in the rangelands (Dickie, 1982). Other technicians had looked at the project over a very short time and had left recommendations that, whether rightly or wrongly, had not been followed (Legast, 1980; Freeman, 1981). Still others had left the project without documenting their efforts.

Without a minimal amount of systematic data, the range manager could not have developed an appropriate Range Management Plan for the area. Therefore the first year of the range manager's field stay emphasized research on all aspects of the livestock and range management system. Since the nature of the research is long-term, the second year of the range manager's fieldwork involved a balancing of research and experimentation with the need to implement (on a pilot scale) some of the more promising recommendations.

This chapter presents a detailed account of all research/experimentation activities. In order to refrain from writing a lengthy book, the author assumes that most readers of this chapter have some familiarity with the fields of ecology, range management and animal science. The "conclusions and recommendations" after each section provides a summary of the salient points of the research.

3.1. RANGE RESOURCE INVENTORY

The range resource inventory was aimed at identifying, locating and describing the resources existing in the rangelands of the project area. They include an inventory of soils, vegetation, water resources, and agricultural land use. However, all of these resources are affected to a great extent by the climate and geology of the area. The following pages give a brief overview of these two aspects.

3.1.1. Meteorological Context

Rainfall in the project zone is dependent to a large extent on the seasonal movements of the intertropical convergence zone. Most of the rainfall occurs in June-October. In January-March there are occasional storms but they provide no more than a trace of rain which dries immediately after the sun reemerges. The first "true" rains of the season are preceeded by 5-30 minutes of strong northeasterly winds which may reach 10 km/h, and which lift and carry a tremendous amount of fine sand and dust for 1-10 km. As a result

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the winds over large expanses of denuded areas (such as Bakel) are dustier than over forested areas (such as Mbaniou).

The first rains tend to be heavy but of short duration, which usually results in very high runoff rates (especially since the soil, coming out of the dry season, usually has little cover to protect it). In good years, the subsequent rainfall events may be 3-7 days apart. However, in 1983 and 1984 (the latter qualifies as a "bad" year), the rains were few and far between.

Table 3.1. provides a summary of rainfall events since 1980. Not only is there a high amount of variability between years, but also between months. In addition, there is a high spatial variability in recorded rainfall. A study done by the project's hydrologist/engineer showed that there is much difference in recorded rainfall even among gauges that are 500 m apart (see Soils/Water Engineering report). The distribution of rainfall over the season and the land may be as important as the total quantity for the germination, growth and maturity of crops and pastures.

TABLE 3.1.

RECORDED MONTHLY RAINFALL IN BAKEL PROJECT ZONE
1980-1984 (mm)

		May	June	July	Aug.	Sept.	Oct.	Total
Bakel	1980	0	5.1	85.0	187.9	94.2	21.0	393.2
Bakel	1981	1.8	1.5	152.5	311.9	56.3	0.5	524.5
Bakel	1982	0	0	179.0	155.8	211.9	48.0	594.7
Bakel	1983	3.0	78.2	97.6	169.6	47.6	2.0	398.0
Bakel	1984	1.9	57.2	33.5	88.9	39.7	28.4	249.6
Mbaniou	1983	-	-	-	-	-	-	475.0
Mbaniou	1984	-	-	-	-	-	-	343.0
Ndiya	1984	3.0	110.5	52.0	76.0	100.0	72.0	413.5
Toulekedi	1984	0	72.2	84.2	85.3	104.3	75.0	421.0

SOURCE: Bakel meteorological station and survey data.

With the end of the rains, the winds change direction and are frequently from the southwest. The "winter" season starts in November/December and lasts until February/March. During this time there are cold, dry winds generally from the southwest which may lower the ambient temperature down to an average of 25°C. But gradually this winter is replaced by a hot and dry period, once again with northeasterly winds and an

ambient average temperature of 36°C. Dust storms are very frequent at this time, which may blanket the area for 3-4 continuous days.

3.1.2. Geological Context

The most important feature of the project zone is the distinct differences in soils, vegetation, and water that exists between the Gambia River and the Senegal River watersheds. The two basins are differentiated by an "escarpment" line that runs roughly north-south, dividing the project zone in half. This escarpment does not exceed 70 m in height, yet it exerts a profound influence on the ecology of the area.

According to Feller (ORSTOM, 1975) the Gambia River Basin is part of the continental terminal and is characterized by a mottled and clayey, sedimentary rock (grés). This is covered by a 1-4 meter layer of ironstone (curasse ferrugineuse). The soils formed from this ironstone tend to be shallow, acidic and loamy.

The Senegal River Basin, on the other hand, has seen a gradual erosion of the continental terminal by the river and its tributaries (especially the Falamé), so that in many areas the bedrock is exposed. The bedrock consists of folded quartz and schist formations. The soils formed from this bedrock tend to be deep and loamy but with a higher percentage of kaolinic clays. Along the eastern edge of the continental terminal over the quartz/schist-derived soils, is a sandy area of about 1-2 km in width, which is a result of the gradual erosion of the continental terminal.

3.1.3. Soil-Vegetation Classification

The range resource inventory was based on field observations of a total of 36 sample sites in the project area over a two-year period. A subsequent manual interpretation of aerial photos (B&W, 1:50,000; OMVS, February 1980) allowed the classification of the entire project area into 11 distinct vegetation types.

According to the UNESCO Vegetation Classification (White, 1983), the entire project area falls within the main physiognomic type labelled "Sudanian Regional Center of Endemism." However, the project area occupies the northern portion of this Sudanian Region and in some cases has features similar to the southern "Sahelian Regional Transition Zone."

Many different criteria can be used to classify the vegetation types in the project area. The present classification is based on a recognition of the following points:

- variations in the plant community covering areas of less than half hectare are not easily distinguishable on the aerial photos;

- the composition of the annual herbaceous community shows substantial variation from year to year, depending on the amount of rainfall and its distribution through the rainy season. But there is a certain stability in the vegetation composition when the mapping units are based on a soil classification;

- the variations in the woody community correlates more with soil type in the long run, than with variations in rainfall, incidence of fire, or grazing.

Therefore, it was decided that the vegetation types would be linked to soil types, and all would be combined into one single map. As a result, the soil-vegetation map shows a general, longer-term inventory of resources, one that can be used over many years. It can also be used for monitoring long-term changes in the vegetation of the zone.

According to White (1983) the climax vegetation of areas receiving 250-500 mm annual rainfall is wooded grassland. Areas in the 500-900 mm isohyet are considered to be woodland to dry forest in their climax state. Without long-term monitoring efforts it is impossible to verify these assertions in the Bakel project area. Even though there are areas within the project zone that may never have been grazed or exploited by people, almost all the areas have been burnt at one point or other. Therefore the vegetation is a secondary (derived) community, or at best it reflects what some authors refer to as a "fire climax" community.

The soil-vegetation map is similar to a range condition map in so far as it treats denuded/degraded lands as a separate classification. However, all other range classes in the map are averages of low to moderate to highly used areas.

Agricultural land use is also included in the soil-vegetation map. This classification reflects lands that currently are being cultivated, or have been cultivated in the past 5-8 years and are now fallow. Unfortunately, it was not possible to distinguish fallow from nonfallow land even on 1:10,000 scale B&W photos.

In the past four years, the administrative boundaries of the general project area have changed twice, and that of the three project zones three times, and they will all undoubtedly change at least once more. Therefore it seems more appropriate that the vegetation classification should follow the more constant geographical boundaries of watersheds. However, the classification, by necessity, also follows the overall boundary of the project area as established by the Commission for Development of Pastoral Units in 1984. Table 3.2. provides a summary of the vegetation classification by reporting the estimated land areas under each range type. A distinction is made between the range types in the Gambia River Basin as opposed to the Senegal River Basin.

TABLE 3.2.

LAND SURFACES IN EACH RANGE TYPE, 1983
(ha)

Range Type	Gambia Basin ha	%	Senegal Basin ha	%	Total ha	%
Ironstone Plateau	82742.5	61.2	0	0	82742.5	32.9
Floodplain	29440.9	21.8	81362.5	69.8	110803.4	44.0
Riparian	405.0	0.3	0	0	405.0	0.2
Swamp	11422.5	8.4	0	0	11422.5	4.5
Hill	0	0	210.0	0.2	210.0	0.1
Foothill	0	0	10857.5	9.3	10857.5	4.3
Degraded	3184.1	2.4	19490.0	16.7	22674.1	9.0
Water	7582.5	5.6	10.0	T	7592.5	3.0
Agriculture	500.0	0.4	4612.5	4.0	5112.5	2.0
Total	135277.5	100	116542.5	100	251820	100

SOURCE: Survey data.

The vegetation communities on either side of the escarpment line are significantly different from each other. Figures 3.1 and 3.2 provide a diagram of typical cross sections through these two areas.

The methodology used for the herbaceous and woody plant inventory consists of a stratified site selection procedure (stratified according to range type and level of use). There are a total of 36 sites distributed in the project zone. The exact location of these sites are given in the base map (Appendix F1.). Within each site, the woody stratum is measured using the Point-Center Quarter method (PCQ), and the herbaceous stratum is measured using a frequency-biomass method. In the PCQ technique, there are 20 points per site. The importance value for each species is a sum of its relative density and relative frequency and relative dominance. For the herbaceous vegetation an open relevé was used to choose the size of the plot for both the frequency and the biomass measures. The final choice fell upon a 0.5 m^2 (circular) plot. There are 10 biomass plots and 30 frequency plots per site.

The main vegetation types used in this report follow the guidelines established by the UNESCO Classification System (White, 1983: 39-55). However, apart from the main

FIGURE 3.1. Typical Cross-section : Gambia River Basin

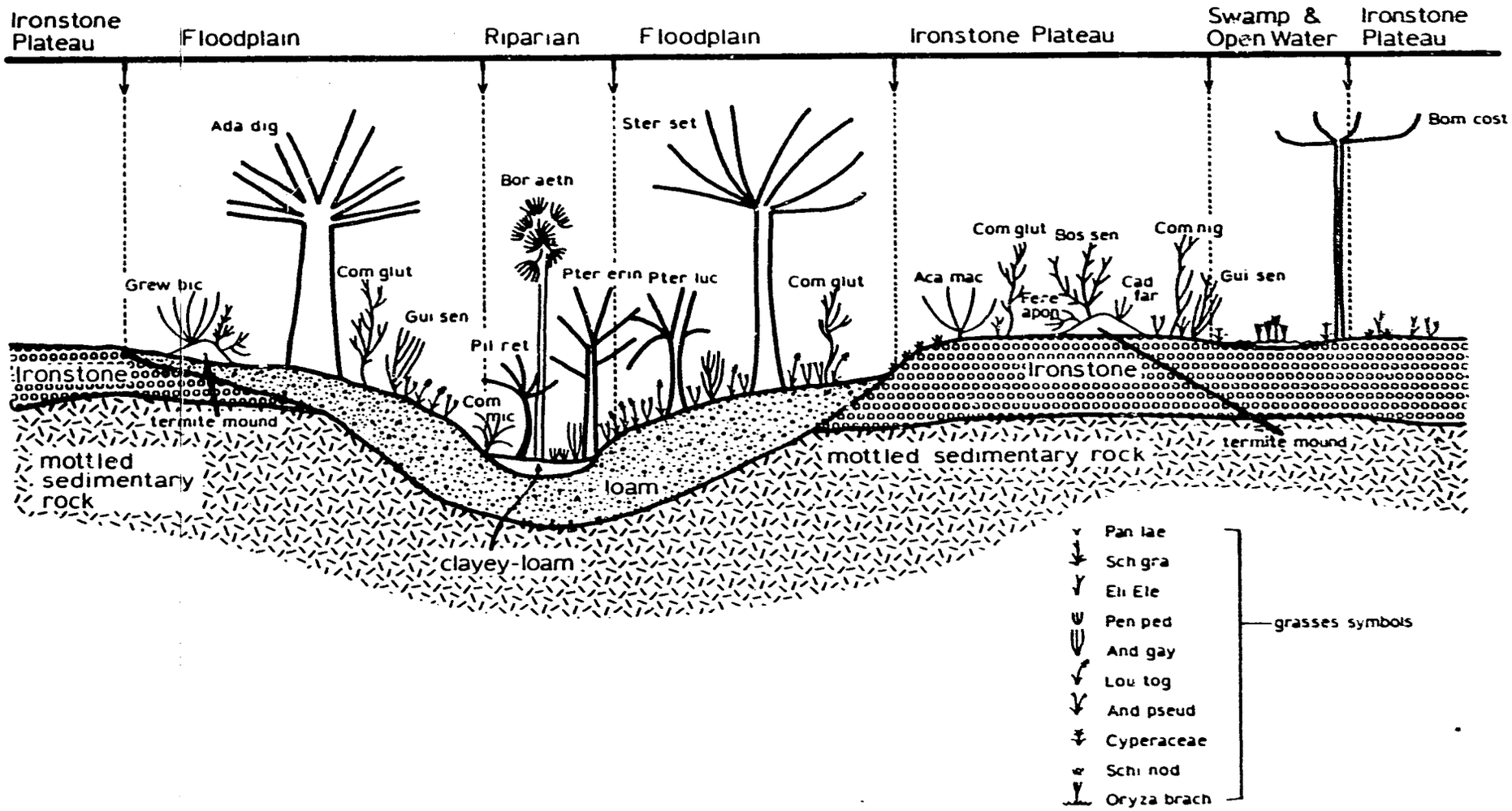
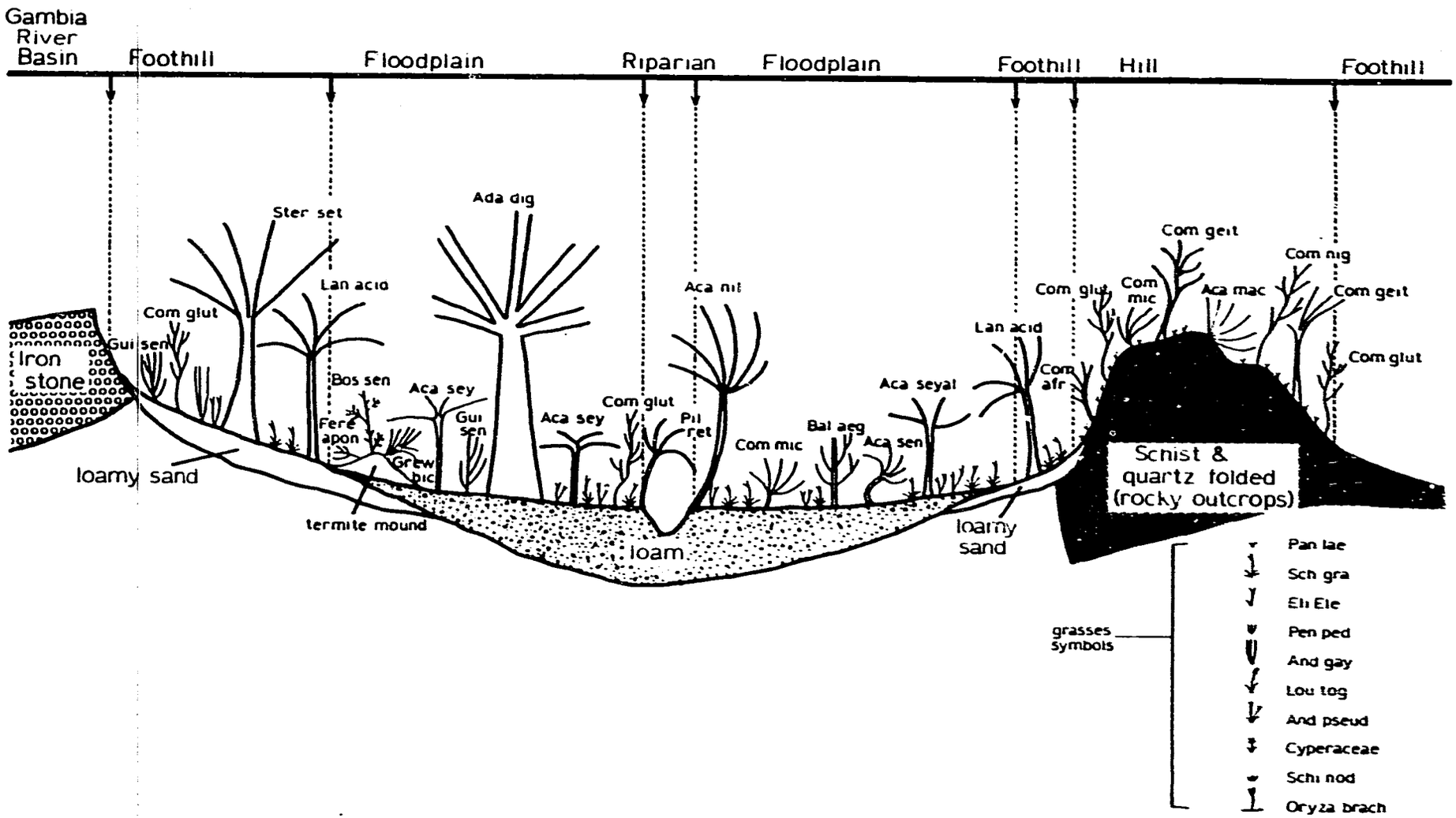


FIGURE 3.2. Typical Cross-section : Senegal River Basin



characteristics of a range type, there are also two regular microvariations in the floristic composition of the range types which are too small to be detected by aerial photos, but which are quite visible on the ground. The first microvariation occurs on termite mounds. On these mounds there is a dominance of Grewia bicolor, Cadaba farinosa, Feretia apondanthera and Boscia senegalensis in the shrub layer, and Aristida adscensionis, Dactyloctenium aegyptium and Microchloa indica in the herbaceous layer. Each mound may cover a 0.5-10 m^2 area. Small termite mounds do not support any vegetation and are not visible on aerial photos. However, large mounds do support vegetation and they were visible on the aerial photos for 6 out of the 11 range types. From these photos it was estimated that on the average there are between 0.2 and 7.2 large termite mounds per hectare, depending on the range type. Microvariations in the vegetation composition caused by termite mounds are very widespread in the Sahel prompting some authors to coin the word "termite mound mosaic or thicket" (White, 1983). Section 3.2.1.1. of this report tries to provide an assessment of the role of termites and their utilization of the rangelands.

The second microvariation occurs wherever there are two or more grouped trees or bushes. This grouping allows a "microclimate" that is shaded from the harsh sun, is less subject to drying winds and probably has more organic matter in the soil (because of fallen leaves, dead roots, etc.). There was a very high correlation between these microclimates and the occurrence of some herbaceous species (Pennisetum pedicellatum, Setaria pallidifusca and various species of the Compositae family), suggesting that these species are more sensitive to dryness and are probably less able to withstand competition in the open grasslands.

The project area as a whole can be said to be a wooded grassland (range types ironstone plateau, floodplains and foothills). However, there are other formations of smaller geographical extent such as edaphic grasslands, riparian communities, hilly bushlands and swamplands. Map F2. provides a detailed illustration of all range types.

Table 3.3. provides a summary of the main characteristics of each range type. The "vegetation type" follows the UNESCO classification system. The "soil texture" is derived from the soil analysis in Appendix A. The "termite mound density" has been estimated by counting the number of termite mounds visible on 1:10,000 B&W aerial photos.

The "tree and shrub" vegetation reflects the results of the PCQ method. "species richness" refers to the number of different species present. The "tree and shrub density" reflects the number of individual plants larger than 1cm in basal diameter, per hectare. The "species composition" is based on the importance value with "1" being the highest

TABLE 3.3.

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Ironstone Plateau[b] VEGETATION TYPE: Wooded grassland

Percent of Project Area:		
	Gambia River Basin	61.2%
	Senegal River Basin	0%
	Total	32.9%

Soil Texture: Horizon

A	gravelly sandy loam	
C	ironstone	
—		
—		

Soil Profiles No. 1,10,11

General Slope of Terrain 0.3% Termite mound density 7.23 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 379.83 per hectare Species Richness 18

Species Composition: Importance Value Rank

1	Gui sen
2	Com glut
3	Aca mac
4	Gre bic
5	Com nig

HERBACEOUS VEGETATION

			Sept. 1983	May 1984	Sept. 1984
	Species Richness		41		35
Species Composition:	Ranked Frequency	1	And pseu		Dih hag
		2	Dih hag		And pseu
		3	Eli ele		Eli ele
		4	Bor rad		Aes schi
		5	Pan heud		Tep brac
Community Biomass: (kg/ha)	Standing biomass		3502.3	152.7	1151.4
	Herb litter			686.3	
	Woody litter			310.3	
	Total biomass		3502.3	839.0	1151.4
	% change in total biomass from 09/83			-76.0[a]	-67.1[a]

NOTES: [a]Significant difference at 0.05 level.

[b]Previously referred to as "Laterite" or "Nyargo."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Floodplain (G)[b] VEGETATION TYPE: Wooded grassland

Percent of Project Area:		
	Gambia River Basin	21.5 %
	Senegal River Basin	0%
	Total	11.53%

Soil Texture: Horizon

A	sandy loam
B	sandy clay loam
C	sandy clay loam

Soil Profiles No. 2,6,7,8,9

General Slope of Terrain 0.3 % Termite mound density 2.51 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 392.45 per hectare Species Richness 22

Species Composition: Importance Value Rank

1	Com glut
2	Gui sen
3	Pter luc
4	Gre bic
5	Ster set

HERBACEOUS VEGETATION

			Sept. 1983	May 1984	Sept. 1984
	Species Richness		55		43
Species Composition:	Ranked Frequency	1	Lou tog		Lou tog
		2	Bor rad		Aes schi
		3	Dih hag		Dih hag
		4	Aes schi		And pseu
		5	And pseu		Eli ele
Community Biomass: (kg/ha)	Standing biomass		1884.9	291.4	975.1
	Herb litter			526.7	
	Woody litter			193.9	
	Total biomass		1884.9	818.1	975.1
	% change in total biomass from 09/83			-56.6[a]	-48.3[a]

NOTES: [a]Significant difference at 0.05 level.

[b]Previously referred to as "Valley."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Floodplain (S)[b] VEGETATION TYPE: Wooded grassland

Percent of Project Area:	
Gambia River Basin	0%
Senegal River Basin	69.8%
Total	32.3%

Soil Texture: Horizon

A	sandy loam
B	loam
C	clay loam

Soil Profiles No. 18

General Slope of Terrain 0-2 % Termite mound density 0.99 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 424.25 per hectare Species Richness 14

Species Composition: Importance Value Rank

1	Aca seyal
2	Fer apon
3	Com mic
4	Com glut
5	Bal aeg

HERBACEOUS VEGETATION

			Sept. 1983	May 1984	Sept. 1984
	Species Richness		42		42
Species Composition:	Ranked Frequency	1	And pseu		Aes schi
		2	Sch gra		And pseu
		3	Dih hag		Pan lae
		4	Aes schi		Zor glo
		5	Bor rad		Bor stac
Community Biomass: (kg/ha)	Standing biomass		2454.2	58.0	1685.6
	Herb litter			558.2	
	Woody litter			72.0	
	Total biomass		2454.2	616.2	1685.6
	% change in total biomass from 09/83			-74.9[a]	-31.3[a]

NOTES: [a]Significant difference at 0.05 level.

[b]Previously referred to as "Plateau."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Degraded floodplain[d] VEGETATION TYPE: Degraded grassland

Percent of Project Area:		
	Gambia River Basin	2.5 %
	Senegal River Basin	0 %
	Total	1.38 %

Soil Texture: Horizon

A	sandy loam
A2	silt loam
B	loam
C	clay loam

Soil Profiles No. 3,4,5

General Slope of Terrain 0-3 % Termite mound density [c] per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 49.25 per hectare Species Richness 15

Species Composition: Importance Value Rank

1	Ster set
2	Gre bic
3	Gui sen
4	Pter luc
5	Bos sen

HERBACEOUS VEGETATION

		Sept. 1983	May 1984	Sept. 1984
Species Richness		29		18
Species Composition: Ranked Frequency	1	Zor glo		Zor glo
	2	Mic ind		Mic ind
	3	Dac aeg		Dac aeg
	4	Era lin		Era lin
	5	Pan lae		Sch gra
Community Biomass: (kg/ha) % Plots denuded		38	100	70
Standing biomass in nondenuded (g/m^2)		21.6	0	28.3
Total biomass (kg/ha)		133.8	0	83.8
% change in total biomass from 09/83			-100[a]	-36.6[b]

NOTES: [a]Significant difference at 0.05 level.

[b]Not significant difference.

[c]Not visible on aerial photos.

[d]Previously referred to as "Degraded" or "Seno."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Degraded floodplain (S) VEGETATION TYPE: Degraded grassland

Percent of Project Area:		
	Gambia River Basin	0 %
	Senegal River Basin	16.7 %
	Total	7.74%

Soil Texture: Horizon

A	sandy loam
B	sandy loam
C	clay loam
—	

Soil Profiles No. 17

General Slope of Terrain 0-3 % Termite mound density b per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 45.04 per hectare Species Richness 10

Species Composition: Importance Value Rank

1	Bal aeg
2	Gui sen
3	Aca Sen
4	Aca seyal
5	Ziz mau

HERBACEOUS VEGETATION

		Sept. 1983	May 1984	Sept. 1984
	Species Richness	12		23
Species Composition: Ranked Frequency	1	Mic ind		Mic ind
	2	Spo fes		Hyb thes
	3	Cas Tor		Zor glo
	4	Sid stip		Hel stri
	5	Zor glo		Cas Tor
Community Biomass: (kg/ha)	% Plots denuded	30	100	50
	Standing biomass in nondenuded (g/m^2)	98.6	0	15.9
	Total biomass (kg/ha)	690.4	0	79.4
	% change in total biomass from 09/83		-100[a]	-88.5[a]

NOTES: [a]Significant difference at 0.05 level.

[b]Not visible on aerial photos.

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Hill[b]

VEGETATION TYPE: Wooded bushland on hills and rock outcrop

Percent of Project Area:		
	Gambia River Basin	0 %
	Senegal River Basin	0.2 %
	Total	0.08%

Soil Texture: Horizon

A	stony sandy loam
R	schist or quartz

Soil Profiles No. none

General Slope of Terrain 15-40%

Termite mound density 1.0 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 368.4 per hectare

Species Richness 16

Species Composition: Importance Value Rank

1	Aca mac
2	Com glut
3	Com nig
4	Com geit
5	Com mic

HERBACEOUS VEGETATION

		Sept. 1983	May 1984	Sept. 1984
Species Richness		47		40
Species Composition: Ranked Frequency	1	Pan lae		Pan lae
	2	And chev		Pan heud
	3	Pan heud		Eri abys
	4	Schi nod		Cleo vis
	5	Dih hag		Ind dend
Community Biomass: (kg/ha) Standing biomass		1834.1	95.3	634.2
Herb litter			333.0	
Woody litter			303.8	
Total biomass		1834.1	428.3	634.2
% change in total biomass from 09/83			-76.6[a]	-65.4[a]

NOTES: [a]Significant difference at 0.05 level.

[b]Previously referred to as "Colline."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Foothill[b] VEGETATION TYPE: Wooded grassland

Percent of Project Area:		
	Gambia River Basin	0 %
	Senegal River Basin	9.3 %
	Total	4.31 %

Soil Texture: Horizon A loamy sand; B sandy loam; C sandy clay loam — Soil Profiles No. 14,15,16,20

General Slope of Terrain 1-4 % — Termite mound density 0.68 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 294.21 per hectare — Species Richness 15

Species Composition: Importance Value Rank

1	Com glut
2	Gui sen
3	Lan acid
4	Gre bic
5	Ster set

HERBACEOUS VEGETATION

		Sept. 1983	May 1984	Sept. 1984
Species Richness		37		31
Species Composition: Ranked Frequency	1	Sch gra		Ari ads
	2	Zor glo		Zor glo
	3	Ari ads		Spo fes
	4	Mer pin		Dac aeg
	5	Spo fes		Sch gra
Community Biomass: (kg/ha) Standing biomass		2967.5	186.0	756.8
Herb litter			1212.8	
Woody litter			0	
Total biomass		2967.5	1398.8	756.8
% change in total biomass from 09/83			-57.1[a]	-74.5[a]

NOTES: [a]Significant difference at 0.05 level.

[b]Foothills refer to two geographical spaces: one is the area immediately to the east of the continental shelf; the other is the area between hills and floodplain on the Senegal Basin (which is too small to show up on the map). Previously referred to as "Escarpment."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Streambed[b] VEGETATION TYPE: Riparian

Percent of Project Area:		
	Gambia River Basin	0.3 %
	Senegal River Basin	0 %
	Total	0.16 %

Soil Texture: Horizon

A	sandy loam
B	silt loam
C	?

Soil Profiles No. 13

General Slope of Terrain 0-3 % Termite mound density 0 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 567.25 per hectare Species Richness 20

Species Composition: Importance Value Rank

1	Com glut
2	Scle bir
3	Ada dig
4	Pter erin
5	Com mic

HERBACEOUS VEGETATION

		Sept. 1983	May 1984	Sept. 1984
Species Richness		76	65	
Species Composition: Ranked Frequency	1	Pen ped		Pen ped
	2	Bac ham		Pan lae
	3	Bor rad		Bor rad
	4	Bor stac		Bra dist
	5	Tri pent		Tep brac
Community Biomass: (kg/ha) Standing biomass		3242.8	144.6	1980.5
Herb litter			1432.8	
Woody litter			321.0	
Total biomass		3242.8	1577.4	1980.5
% change in total biomass from 09/83			-51.4[a]	-38.9[a]

~~NOTES:~~ [a]~~Significant difference at 0.05 level.~~

[b]Streambeds in the Gambia Basin normally have a width of 10-100m. The slopes of the bed are gradual, and the water flow is relatively slower, therefore plants can establish in the bed. Previously referred to as "River."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Streambed[a] VEGETATION TYPE: Riparian

Percent of Project Area:		
	Gambia River Basin	0 %
	Senegal River Basin	? %
	Total	? %

Soil Texture: Horizon A sandy loam; B sandy loam; C ?; — — Soil Profiles No. 19

General Slope of Terrain 0-2 % Termite mound density 0 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density ? per hectare Species Richness ?

Species Composition: Importance Value Rank

1 Pil ret
2 Aca nil
3 Aca seyal
4 Aca Sen
5 Com mic

HERBACEOUS VEGETATION

		Sept. 1983	May 1984	Sept. 1984
	Species Richness	0		0
Species Composition: Ranked Frequency	1			
	2			
	3			
	4			
	5			
Community Biomass: (kg/ha)	Standing biomass			
	Herb litter			
	Woody litter			
	Total biomass	0	0	0
	% change in total biomass from 09/83			

NOTE: [a]Streambeds in the Senegal Basin are relatively narrow (1-20m) with steep slopes, and fast moving water. There normally are a few trees on the upper edges of the slopes, but there is hardly any herbaceous community.

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Open water[a] VEGETATION TYPE: Herbaceous fresh-water aquatic swamp

Percent of Project Area:		
	Gambia River Basin	5.6 %
	Senegal River Basin	T %
	Total	3.02%

Soil Texture: Horizon

A	clay
B	clay
C	?

Soil Profiles No. 21

General Slope of Terrain 0 % Termite mound density 0 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 0 per hectare Species Richness 0

Species Composition: Importance Value Rank

1	
2	
3	
4	
5	

HERBACEOUS VEGETATION

			Sept. 1983	May 1984	Sept. 1984
	Species Richness		24		24
Species Composition:	Ranked Frequency	1	Bra dist		Aes tamb
		2	Hyg sen		Cyp Iria
		3	Bul barb		Hyg sen
		4	Ory brac		Fim exi
		5	Bra stip		Bra stip
Community Biomass: (kg/ha)	Standing biomass				
	Herb litter				
	Woody litter				
	Total biomass		?	?	?
	% change in total biomass from 09/83				

NOTE: [a]Previously referred to as "Water."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Swamp[d] VEGETATION TYPE: Edaphic grassland on temporary waterlogged depression with scattered tree mozaic

Percent of Project Area:		
	Gambia River Basin	8.4 %
	Senegal River Basin	0 %
	Total	4.54 %

Soil Texture: Horizon A clay loam; B ironstone

Soil Profiles No. 12

General Slope of Terrain 0 % Termite mound density [c] per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density 90.53 per hectare Species Richness 24

Species Composition: Importance Value Rank

1	Com glut
2	Com nig
3	Ada dig
4	Gre bic
5	Gui sen

HERBACEOUS VEGETATION

		Sept. 1983	May 1984	Sept. 1984
Species Richness		52		34
Species Composition: Ranked Frequency	1	Lou tog		Lou tog
	2	And pseu		Mic ind
	3	Mic ind		Dac aeg
	4	Hel stri		Dih hag
	5	Dih hag		Hel stri
Community Biomass: (kg/ha) Standing biomass		2078.9	0[a]	1850.2
Herb litter				
Woody litter				
Total biomass		2078.9		1850.2
% change in total biomass from 09/83			-100[a]	-11.0[b]

NOTES: [a]All sites burnt.

[b]Not significant difference.

[c]Not visible on aerial photos.

[d]Previously referred to as "Depression" or "Mushroomland."

TABLE 3.3. (con't.)

SUMMARY OF RANGE RESOURCES 1983-1984

RANGE TYPE CODE: Cultivated & fallow fields

VEGETATION TYPE: Anthropic shrubland

Percent of Project Area:	
Gambia River Basin	0.5 %
Senegal River Basin	4.0 %
Total	2.1 %

Soil Texture: Horizon

A	sandy loam
B	sandy clay loam
C	sandy clay loam

Soil Profiles No. 6,7

General Slope of Terrain 0-3 %

Termite mound density 2.5 per hectare

TREE AND SHRUB VEGETATION (1983)

Total Tree and Shrub Density ? per hectare

Species Richness ?

Species Composition: Importance Value Rank

1	Com glut
2	Gui sen
3	
4	
5	

HERBACEOUS VEGETATION

		Sept. 1983	May 1984	Sept. 1984
Species Richness		?		?
Species Composition: Ranked Frequency	1	Pen ped		
	2	Cas Tor		
	3			
	4			
	5			
Community Biomass: (kg/ha) Standing biomass				
Herb litter				
Woody litter				
Total biomass				
% change in total biomass from 09/83				

rank, and excludes rare species. The plant's name is abbreviated to the first three letters of the genus and the first three letters of the species. A full list of the plants can be found in Appendix C.

The "herbaceous vegetation" reflects data from the frequency and biomass methods. "species composition" is based on a ranking of relative frequencies. The "community biomass" is described by the dry matter weight of the herbaceous plants existing at any one point in time. "Standing biomass" refers to dry matter that is rooted. "Herbaceous litter" refers to fallen fragments of stems, leaves, etc. and "woody litter" refers to fallen tree leaves, fruits and flowers. This litter is an important part of the total community biomass in the dry season, and is very much exploited by livestock.

3.1.4. Conclusions and Recommendations

The natural resources within the project zone are very much influenced by the geological feature of the continental shelf. This shelf divides the area into two very separate areas, each with its own distinct soil, vegetation and geological formations and potentials. These differences necessitate slightly different development strategies.

The range inventory is a useful tool for overall resource planning. This particular inventory was also designed in order to allow long-term ecological monitoring. The PCQ and frequency-biomass methods are fast and easy, and require very few tools, none of which are sophisticated. Given the problems of environmental degradation, to be discussed in the following sections, the author strongly recommends that the project (or other research institution) initiate a long-term ecological monitoring program that would allow a yearly collection of data from the inventory sites. It is recommended that the woody strata be monitored at least every five years, and that the herbaceous strata (and rainfall) be monitored every year.

Finally, the fact that the herbaceous community is an annual one necessitates a tremendous amount of flexibility in planning the use of the range. Yearly inventories are not useful planning tools, nor are static calculations of "carrying capacities." What is required is a flexible system based on a yearly evaluation of the range conditions. This point is further elaborated in the Range Management Plan.

3.2. RANGE UTILIZATION

The previous sections dealt with the description of the existing soils and vegetation in the project zone. However, an evaluation of these resources cannot be made unless we know how the rangelands are being utilized. This section discusses the patterns of range

utilization by livestock and people. Unfortunately the author did not have enough time to study the role of wildlife. However, as far as the Gambia Basin is considered, the OMVG Research Team has done an extensive survey of the wildlife in the project area in 1983-84 (University of Michigan, Gambia River Basin Studies, forthcoming reports). In addition, the socioeconomist made a record of the birds and mammals sighted in the project zone (see Appendix B.).

3.2.1. Use by Livestock

This section will deal with both the larger, seasonal movements of livestock in the project zone, as well as the smaller daily grazing patterns.

3.2.1.1. Seasonal livestock movements

In the wet season, all project livestock tend to remain close to their villages of origin. However, in the dry season, the location of the livestock depends primarily on the availability of water, but also on the spread of bush fires. If there is not enough water in the village well, or if a fire has devastated the pastures for hectares, then the cattle are sent off, either on a long or on a short transhumance. The long transhumance normally starts in December (ie., after the harvest). The traditional pastures used for these long-term camps were along the Falamé, to the east of the project. However, the increase in grazing pressure over the years has gradually degraded these areas. The cattle are now forced to travel further south along the Falamé River and even as far as Kenieba in the Republic of Mali.

The short transhumance is usually in response to a shortage of water for the last 3-4 months of the dry season. In this case, the cattle will be taken to the nearest village with a good supply of water and pastures. In most cases the cattle are then entrusted to a relative in that village who will herd them with his own cattle. If there are no relatives, then a herder is hired for the job. Small ruminants and other livestock are left in the village of origin year-round since they consume relatively less water than the cattle herd, and they are primarily browsers who can normally find some forage even in burnt pastures.

Apart from project livestock, the only other livestock that use the project zone are owned by the nomadic Peul. There are two groups of Peuls, one from northern Senegal ("Ferlo") and the other from Mauritania. These livestock are usually accompanied by a herder and a small retinue of people. However, in bad years when crops fail in the north, more members of the extended family as well as other livestock (camels, small ruminants, donkeys) will accompany the herd.

The nomads use the project zone in two distinct period: the first in November/December when they move south to the Kedougou area for the dry season, and the second in June/July when they are returning up north. Their movements are very

tightly linked to the rainfall patterns and can be called "opportunistic." However, in general, it appears that they use the western part of the project area only as a temporary step in their long migration. In 1983, a total of eight herds were camped in the Gambia Basin for an average stay of 1.5 months in June/July. In November/December of that year there were only five camps who stayed for 3-4 weeks. Although a few camps may have been missed in the counting, nevertheless, it is clear that the magnitude of transhumance in the Gambia Basin is much lower than was previously estimated. However, in the Senegal Basin, because of the fact that there is a river that is freely used by all, the number of nomads is probably much greater, but exact figures are very hard to come by.

The nomadic Peul are seen as a problem in the project zone. Government officials see in them the epitome of lawlessness and lack of control. Project personnel see the technical problems associated with overgrazing and spread of livestock disease and epidemics. It is not surprising, therefore, that the Peul tend to avoid government officials or questions. When confronted, the people will blame bush fires, dead kobas and any other illegal action on the nomads. However, the people value their association with the nomads. They benefit from the manure left by the nomadic herds on their fields, and have the opportunity to buy their Zebu cows who are known to have a higher milk production.

The movements of the nomadic Peuls, just like the internal movements of the project's livestock population, is a matter of necessity. Staying in a place with no water or forage is the height of stupidity, and forcing a people to do so, is inhuman. Therefore, at least for the short-term, given little change in existing conditions, we have no choice but to tolerate the nomadic movements in the project zone. But we can also go one step beyond, and actually incorporate them in the Range Management Plan. This point will be elaborated in Chapter 5.

3.2.1.2. Use of Water-points

The use of rangelands and pastures in the project zone depends on various factors such as the availability of forage, the relative palatability of species, seasonal variations in the quantity and quality of the forage, bush fires, and the location of natural mineral "licks." But the most important factor, especially in the dry season, is the availability of water. In the rainy season water can also become a limiting factor because dry spells that last longer than one week will cause the smaller ponds to dry up.

Before the advent of the project, the only sources of water for livestock or people in the dry season were village wells, ceanes (hand-dug shallow wells in riverbeds) and a few natural ponds that held water until November or December. This meant that all of the livestock were concentrated in a 5 km-radius around the villages.

Since 1978 the Project has built 19 water catchment ponds in the Gambia Basin area. The main purpose of these ponds was to allow access into distant pastures that previously could be used very lightly because of the lack of water. It was hoped that the ponds would thus relieve the pressure off the areas around the villages, eventually resulting in regeneration of degraded areas.

Four of the ponds built by the project have been located less than one kilometer from a village because of demands by the villagers. Unfortunately, these ponds do not respond to any range management principles, and have contradicted the objectives of the project since they have tended to attract more livestock from outside the project zone to the already heavily used areas around the villages. The rest of the ponds are located 4 to 12 km from any village.

Three ponds in 1983 and a fourth in 1984 were chosen for intensive monitoring. Several graduates of the project's functional literacy program were hired to count the number of livestock and wildlife watering at these ponds, and to indicate which village the livestock belonged. Two of these ponds (#10 and 16) are located next to villages, one pond (#2) is 4 km away, and the fourth is 7 km away from a village. Each pond was monitored for three consecutive days every two weeks. Table 3.4. provides an extrapolation of the data, indicating the estimated daily number of large and small ruminants drinking at the ponds.

TABLE 3.4.

AVERAGE NUMBER OF LIVESTOCK VISITING PONDS PER DAY
1983/84

	Rainy Season		Camp Season		Dry Season	
Pond No.	Cattle	Sheep & Goat	Cattle	Sheep & Goat	Cattle	Sheep & Goat
1	411	0	n.a.	n.a.	n.a.	n.a.
2	166	0	173	0	0	1136
10	77	0	76	0	147	0
16	136	107	47	128	481	116

SOURCE: Survey data.

The study shows that in the rainy season (June-September) the ponds are used fairly heavily by cattle, while small ruminants tend to rely more on small ponds or watering basins in the village. In the camping season (October-November) the cattle are usually

taken away from the village and permanent camps are set up for one month near a source of water, usually 3-6 km away from the village, in order to protect the harvest from the fields. During the dry season (December-May) there is a doubling of the number of livestock using the ponds. This is primarily because all natural ponds have dried up, but also because outsiders (either nonproject neighbours, or nomads) have come to the area. Table 3.5. shows the relative ownership of the livestock counted at the ponds.

The data show that the use of the ponds by local livestock is primarily a function of the distance to the village. It also shows that transhumants tend to use the distant ponds. Both findings are not surprising. Local livestock are not herded and return to the village every night, therefore they cannot walk too far. The nomadic herds are herded and prefer to use the pastures surrounding the distant ponds.

TABLE 3.5.

PERCENT COMPOSITION OF LIVESTOCK VISITING PONDS BY PLACE OF ORIGIN, 1983/1984

Pond No.	Type of Livestock	Nearest Village to Pond	Other Project Village	Non-Project Village	Nomads	Total
1	cattle	40	40	0	60	100%
2	cattle sheep & goat	94 33	3 0	0 0	3 67	100% 100%
10	cattle	81	19	0	0	100%
16	cattle sheep & goat	97 100	2 0	1 0	0 0	100% 100%

SOURCE: Survey data.

For the project zone as a whole, there has been two major changes as a result of ponds. The first is that the villages that are 6-12 km from any pond have not had to go on the long tranhumance as before, because the cattle are capable of walking every day to the ponds. This has resulted in a saving of well water so that they have been able to water the cattle at the village after the ponds dried up for the rest of the dry season. Villages in the Gambia River Basin, and those immediately to the east of the continental shelf fall in this category.

The second impact of the ponds is felt in the rainy season. During this period small natural ponds will dry up if there is no rain for more than 4-7 days. However, the project ponds remain full from the very first rain, and allow continuous use of the distant pastures.

Water-points normally must be considered as "sacrifice points" and a certain amount of deterioration of the land immediately adjacent to it must be expected. The range manager's task is therefore to reduce the radius of this deterioration by providing enough water-points to decentralize the animals.

In the Gambia Basin area, there is approximately 130,000 ha of pastureland. With a conservative stocking capacity of 4.7 ha/UBT/245 days of the dry season (see section 3.5), these pastures can theoretically support 27,530 UBT. This assumes that the livestock are distributed uniformly on the range. Each UBT will require 7.4 m^3 of water to sustain it during the dry season (at a rate of 30 litres/UBT/day). As a result a total of 203,700 m^3 of water is required for all the livestock. If each water-point could provide 8000 m^3 of water during the whole of the dry season, then a total of 25 water-points would be needed. These 25 water-points will mean that theoretically any part of the range would be <u>less</u> than 6 km from a water-point.

The original project document (CID, 1978) proposed that a total of 30 ponds be built. However, subsequently we have found two constraints. The first is that the effective water available for livestock during the dry season from these ponds, after infiltration and evaporation have taken their toll, ranges from 100-2000 m^3 (Clark, 1984: 8). At the maximum rate, the area would need 100 ponds!!

The second constraint is that the ponds can only be built in the floodplains along the streambeds. This is because the ironstone horizon on the plateau areas is shallow and impedes the digging of ponds. Even though we could theoretically build at least 35 ponds in the Zone (150 km of drainage way and 4 km between ponds), we could never achieve a totally uniform distribution of water-points because the drainage ways themselves are not distributed uniformly. As a result, we clearly need to consider other forms of water-point development for the project area. This is further elaborated in Chapter 4.

But are the project ponds drawing the pressure away from the village areas? Probably yes, however it is too soon to measure the improvement in the soil and vegetation around villages since, in contrast to the process of degradation, the process of regeneration is a very slow one. It may take many years for the full impact to be felt. However, given the extent of the degradation, one cannot expect the project ponds by themselves to solve the problem. The solution to degradation must include, simultaneously, a water development program, revegetation and reforestation, and changes in the management strategy. These points will be discussed further in the Range Management Plan (Chapter 5).

3.2.1.3. Use of Pastures

In the 1983/84 period surveys were carried out to answer two research objectives concerning the use of pastures. The first objective was to understand the geographical patterns of daily grazing by cattle and small ruminants. The second objective was to observe the daily diet of a sample of livestock, and to see how it varied with the season.

The daily movements of livestock in the dry season were observed to be generally centrifugal from the village, that is, as the dry season advanced, the livestock walked farther away from the village. However, the pattern in the rainy season was less clear. Therefore, a survey was conducted in June-September 1984, to study the spatial patterns of grazing and to find out what range types were used more frequently.

The survey was conducted by a graduate of the project's functional literacy program who would follow a herd of cattle every two weeks for three consecutive days. One sheep and goat flock was followed (also on three consecutive days) every other week. The researcher would record what the animals were eating in a five-minute observation period every half-hour. The researcher would also record his geographical position on a 1:25,000 scale map of the area every half-hour. The results are presented graphically in Figure 3.3.

The data have been divided into early in the rainy season, mid-season and end of the rainy season, and superimposed on a grid equivalent to 500 m x 500 m. Each time that the livestock passed through, the grid would be marked once. Therefore the figures illustrate the frequency or presence of livestock. This data cannot be converted directly into grazing density (or number of livestock per hectare per unit time).

As the figures illustrate, there was a fairly distinct change in the general direction taken by the livestock from one part of the season to the next. In the early part of the rainy season, the cattle tended to use the east/southeast part of the range, and travelled an average distance of about 7 km from the village. In mid-season, they used the north/northeast/east part and travelled an average distance of 6 km. In the end of the season, they used the northwest/north/northeast part and moved a maximum distance of 4 km.

The sheep and goats did not tend to change their directions much. In the early part of the season they tended to use all directions, and moved a maximum distance of 6 km. In mid-season to late part of the season, they tended to concentrate more on the northeast and southwest sides, and moved closer to the village.

These data show that on the one hand, the livestock tend to use the same general areas for many weeks. On the other hand, it suggests that the daily grazing in the rainy season is centripetal, ie., the livestock move closer to the village as the season advances.

FIGURE 3.3. MOVEMENTS OF THE SAMPLED CATTLE AND GOATS,
June-September 1984

CATTLE

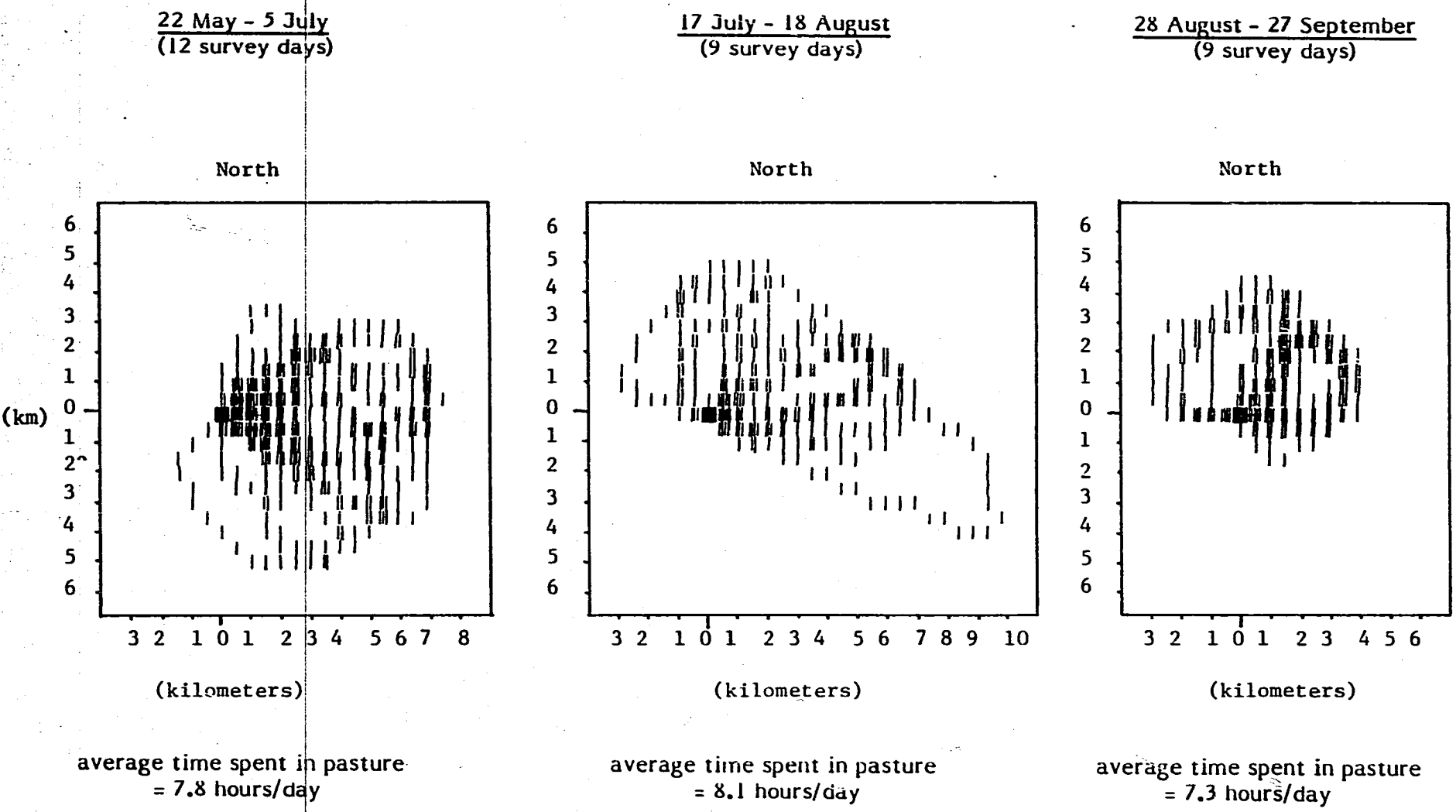
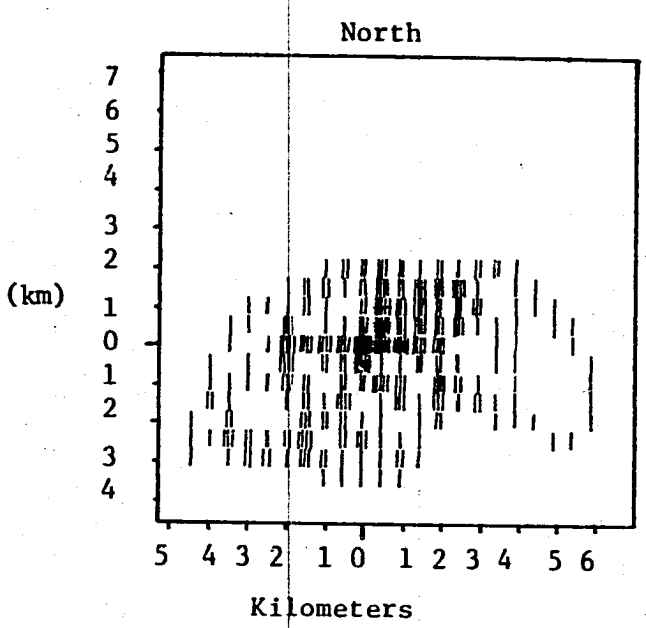


FIGURE 3.3. (con't.)

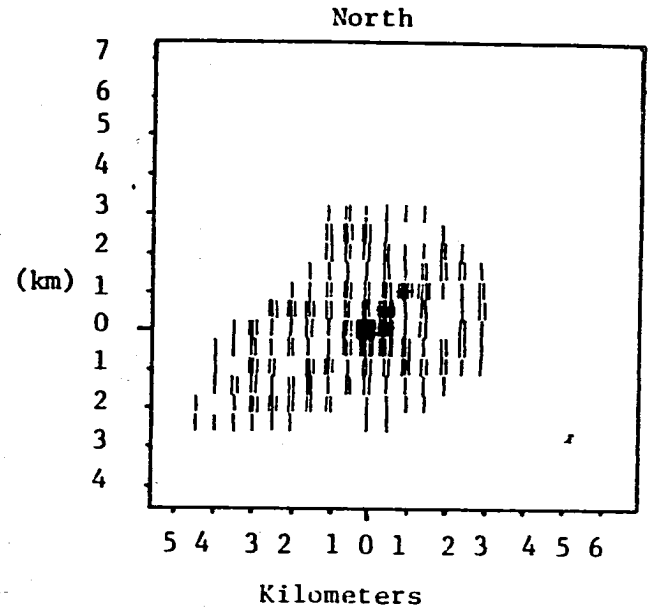
GOATS

29 May - 12 July
(12 survey days)



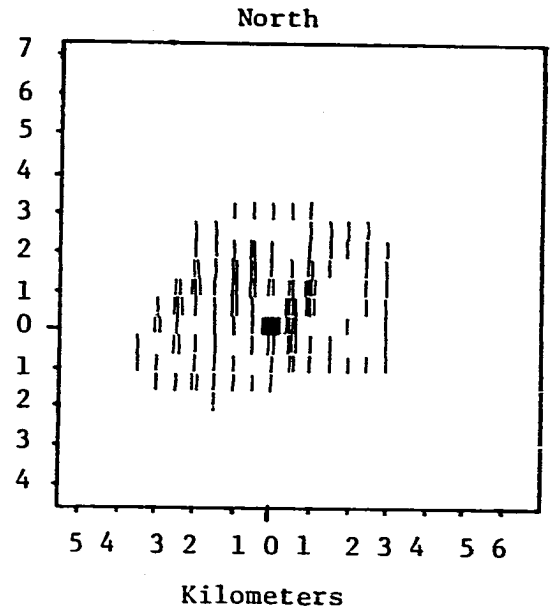
average time spent in pasture
= 5.7 hours/day

25 July - 23 August
(9 survey days)



average time spent in pasture
= 6.2 hours/day

4 - 20 September
(6 survey days)



average time spent in pasture
= 5.9 hours/day

NOTES: ■ Village.
The axes show distance from the village.
Each mark represents presence of herd/flock in a 500m x 500m area each day.

This result may be due to the fact that at the beginning of the rains, the newly germinating plants have relatively less total biomass, and so the livestock have to travel further to get their full ration, than later in the season when the plants have grown.

Table 3.6. correlates the movements of the livestock with the range type. The data show that the denuded and floodplain areas are receiving a disproportionately greater amount of use than the ironstone or swamp range types. In addition, the floodplains tend to be used more heavily in the early part of the season (which is precisely the time that the soils and vegetation are most vulnerable to degradation). The swamplands receive slightly more use at the end of the season because their natural ponds tend to last longer than the ponds on other range types. The floodplains and denuded areas are receiving heavier cumulative use not because of any special quality plant but simply because they are closer to the village.

TABLE 3.6.

USE OF RANGELANDS BY SAMPLE HERD
JUNE/SEPTEMBER 1984

Range Type	Percent of Land Area	Cattle % Use in Season			Sheep & Goats % Use in Season		
		early[a]	mid[b]	end[c]	early	mid	end
Ironstone	65	38	48	47	35	32	38
Floodplain	23	35	25	15	31	33	24
Swamp	9	9	10	17	6	6	19
Denuded	3	18	17	21	28	29	19
Total	100	100	100	100	100	100	100

SOURCE: Survey data.

NOTE: [a]Early season: 22 May - 12 July
[b]Mid-season: 17 July - 23 August
[c]End season: 28 August - 27 September

The second objective of this part of the research activities was to monitor the eating habits of livestock and to study the variations in their diet following the seasons. Two complementary studies were conducted; the first, a "bite-count survey" was done by the range manager. In this study a herd and a flock are followed for the whole day and the number of bites taken from each plant species, the distance travelled, and the time spent

on other activities (ruminating, milking, watering, etc.) are recorded. This survey was done once every three months. The second study, a fecal analysis, involved the collection of fecal matter from the same livestock and times as above. These samples were sent to the Colorado State University Composition Analysis Laboratory. The laboratory then performed a microhistological study to determine the composition of the undigested plant parts in the fecal matter, from which it may be possible to estimate the composition of the feed intake.

Unfortuantely, the results of the fecal analysis are not as reliable as was initially expected. There are major discrepancies between the laboratory analysis and field observations that are not very easily explainable. It appears that the fecal analysis has consistently overestimated the importance of woody species in the diet. Furthermore, contrary to all previous research, the fecal data do not show any seasonal variations. In addition, the data have very high standard deviations, that make the compositional differences (whether by plant species or by season) statistically insignificant. Finally, the fecal analysis appears to have made several mistakes in identifying the plants, since they report species that do not occur in the project zone. Therefore, it was decided that, for all its faults, the bite-count survey would be used as the only source of data on the diet of livestock.

The methodology of the bite-count survey consisted of five-minute observations every half-hour of three different cows in the same herd. Therefore, a total of fifteen minutes were spent every half-hour counting the number of bites taken per plant species, and recording the activity of the cows. In the remaining fifteen minutes, the route taken and the distance travelled were marked on an aerial photograph (1:50,000 scale). In addition, what was estimated to be twenty bites of each key plant, were cut by hand, and later dried and weighed. The same procedure was repeated the following day on three goats. The decision was made not to follow sheep because, on the one hand, sheep tend to run with the goats and on the other, their diet composition is normally in between that of the cow and the goat.

Initial analysis of the first surveys showed that there was no confidence in the size (or weight) of the bites recorded for the cattle, mainly because of two reasons. The first was that the cattle are not very selective, and will take a mouthfull of 3-4 different plant species at the same time. The second reason appeared to be that there was a lot of variability in the size of each bit which did not correlate with the type of plant, but rather with what had been bitten off previously. The bites counted for the goats were more reliable because goats tend to be much more consistent and selective.

The data were thereafter gathered as frequencies of grazing. In other words, each species of plants grazed was recorded only once in each five-minute period. These frequencies were then added up for the whole day, and the relative frequency (in percent) was then calculated. This technique has two shortcomings: it will tend to overestimate the light weight plants (especially Aeschynomene Schimperi and Pandiaka Heudelotii) and will underestimate the heavier plants (Borreria stachydea) or plant parts (fruits of Sterculia setigera and baobab). But in general, this technique provides a good approximation of the diet composition of livestock.

Table 3.7. summarizes the data on time spent on activities. There are significant seasonal variations in the distance travelled as well as time spent on most activities. In the early to mid-rainy season (August) the livestock have to travel relatively far in order to consume their full. At the beginning of the dry season (November) they stay around the village in order to consume the postharvest residue (note the increase in time spent scavenging around the village). The mid-dry season has the longest distances travelled because good quality feed is hard to come by. The end of the dry season has slightly shorter distances mainly because the trees start to get their new buds, which is a main source of feed for all livestock.

Table 3.8. summarizes the data on the feed composition for cattle. In the diet of cattle, grasses do not fall below 45% of the total intake. In August, there is a higher percentage intake of forbs than grasses, reflecting the availability of annual forbs, and there is no consumption of woody species. However, as the dry season advances, the relative share of grasses and woody species increases, and that of forbs decreases. Most forbs (especially legumes) shatter and disappear during the dry season. The forbs that are consumed have large, seedy inflorescences (eg., Lepidagathis anobrya or Borreria stachydea), or are bulbous perennials (such as Asparagus Pauli-Gulielmi) that tend to green up in May along with the new buds on the trees).

Boscia senegalensis, the nondecidious bush, is increasingly consumed as the dry season advances. "Litter" refers to fallen dead leaves or flowers, especially of Combretum micranthum or Boscia angustiflora; at the end of the dry season the cattle may have depleted most of the Boscia senegalensis supply within reach, and resort to this litter. Schizachyrium nodulosum and Brachiaria distichophylla are short grasses that remain leafy all year around. The supply of Brachiaria distichophylla runs out faster than Schizachyrium nodulosum because the former tends to grow only in the "microclimate" created by a group of trees. However, even the Schizachyrium spp. starts to be of short supply in May, and the cattle must consume the more stemmy Andropogon pseudapricus.

TABLE 3.7.

AVERAGE AMOUNT OF TIME SPENT ON DIFFERENT ACTIVITIES AND DISTANCE TRAVELLED PER DAY BY CATTLE AND SMALL RUMINANTS IN 1983/84

Type of Livestock	Month Surveyed	Time spent on Activities (hours:minutes)						
		Sleeping and Standing	Walking Only	Grazing and Walking	Scavenging at Village	Licking Soil or Minerals	Watering	Distance Travelled km/day
Cattle	August	16:15	1:23	6:04	0	0:03	0:15	15.75
	November	16:35	0:35	6:25	0:05	0:15	0:15	9.5
	March	15:40	1:35	6:05	0:20	0:05	0:15	17.6
	May	14:40	1:55	7:10	0	0	0:15	11.25
Small Ruminants	August	16:45	0:10	6:45	0:05	0	0:15	5
	November	18:05	0	4:0	1:40	0	0:15	2.5
	March	16:15	0:10	6:10	1:10	0	0:15	13.7
	May	19:05	0:20	4:0	0:20	0	0:15	9.0

SOURCE: Survey data.

TABLE 3.8.

COMPOSITION OF DAILY DIET OF CATTLE IN 1983/84
(% relative frequency)

	August	November	March	May
Total grasses (Dominant species)	45.7 (Dih hag)[a]	50.6 (Schi nod & Bra dist)	57.3 (Schi nod)	67.7 (And pseud & Schi nod)
Total forbs (Dominant species)	54.3 (Pan heud & Asp Paul)	33.1 (Pan heud & Aes schi)	20.8 (Lep ano)	1.3 (Asp Paul)
Total woody (Dominant species)	0	16.3 (Bos sen)	21.9 (Bos sen)	31.0 (litter & Bos sen)
All Plants	100	100	100	100

SOURCE: Survey data.

NOTE: [a]Complete names of plants can be found in Table C1.

Table 3.9. summarizes the data for goats. The share of forbs in the goats' diet is never below 56%. In August and November the goats may eat some grasses, but not in March or May. The dominant forb in August is Zornia glochidiata, a small leguminous plant with a very high protein content that tends to dominate the degraded lands. During the dry season, the dominant forbs eaten are the hardy, seedy plants (Borreria stachydea and Lepidagathis anobrya).

In conclusion, the data show that cattle rely very heavily on the woody species during the dry season. In general, the diet of cattle and goats is primarily a function of the relative availability of forage on the range, and not solely a function of its "preferability."

Fortunately the incidence of toxicity of livestock due to toxic plants appears to be low in the project zone. The problem of bloat, which occurs quite frequently in June/July could be averted by assigning herders who would restrain the animals from eating the young legumes.

3.2.2. Use by People

Many plant species in the rangelands are used by people for aesthetic, medicinal and religious uses, as well as for tools, construction material, food an fuelwood. The socioeconomic study (see Socioeconomic Study report) can give an indication of the extent to which these plants are used in food. In addition, a study was done by the range manager on the prices of these range and forest products in the Bakel market in July 1984. These are presented in Table 3.10.

The Bakel area traditionally has been a major source of gum arabic (which is derived from Acacia Senegal). Although figures for Bakel are not available, the national register was 4000 T of gum exported from Senegal in 1968. Similar figures for other countries were: Nigeria 2000 T/year and Sudan 40,000 T/year (Kerharo, 1974: 566). The gum arabic sold in the Bakel market is red-colored which may indicate that it is not tapped. The people gather the gum that squeezes out naturally through cracks in the bark.

It is recommended that a survey be conducted to measure the quantity of range and forest products being used for tools, construction, medicine and especially fuelwood. This survey would be needed immediately at least for the fast growing town of Bakel, in order to help devise a reforestation program for the area.

3.2.3. Conclusions and Recommendations

Research done on the patterns of range use by livestock show that it is primarily a function of the availability of water. Water determines the seasonal movements of livestock, as well as the use of distant pastures. However, the availability of specific forage species which is determined by the range type, the season, and the incidence of bush fires, is also a very important determinant of the use of pastures by all types of

TABLE 3.9.

COMPOSITION OF DAILY DIET OF GOATS IN 1983/84
(% relative frequency)

	August	November	March	May
Total grasses	13.0	3.4	0	0
Total forbs (Dominant species)	57.3 (Zor glo)	87.4 (Bor stac)	66.5 (Bor stac)	93.0 (Lep ano)
Total woody (Dominant species)	29.7 (Aca seyal & Aca atax)	9.2 (Mit iner & baobab fruit)	33.5 (Fruits of Pil ret & Aca nil)	7.0 (Fruit of Gre flav)
All plants	100	100	100	100

SOURCE: Survey data.

TABLE 3.10.

PLANTS AND PLANT PARTS FOUND IN THE BAKEL MARKET, JUNE 1984

Scientific Name	Plant Part	Unit	Price/Unit	Habitat[a]	Uses
Acacia Senegal	gum	275 gm	300	L	additive to food, adhesive
Acacia Seyal	branches	136 gm-DM,[b] or 115 cm long, 1 cm wide	125	L	toothbrush
Adansonia digitata (Baobab)	fiber	72 gm, or 292 cm long	125	L	rope
Adansonia digitata	leaf powder	530 gm	200	L	food
Adansonia digitata	fruit	handfull	50	L	food
Borassus aethiopum	leaves	woven	125	L	fan, 25 cm x 25 cm dimensions
Cassia sieberiana	wood & roots	314 gm	50	L	antiparasitic & antidiarrhetic medicine
Cassia Tora	leaves	350 gm-WW,[b]	25	L	food legume
Cola nitida	nut	75 gm, or 4 nuts	100	S	tranquilizer, energiser, drug, food
Combretum glutinosum	powdered fruit	13 gm-DM	100	L	veterinary medicine
Combretum micranthum	leaves	101 gm-DM	25	L	infusion used as medicine (diarrhea, malaria, bronchitis, cough, spleen, etc.)
Cyperus Iria	root nodules	101 gm	50	L	incense
Cyperacea (?)	root nodules	25 gm	10	S	food
Hibiscus esculentus	seed	48 gm	75	L	for growing okra
Hibiscus sabdariffa (red variety)	flowers	7 gm	25	L	food, infusion
Hibiscus sabdariffa (red variety)	seed	10 gm	10	L	for planting
Hibiscus sabdariffa (green variety)	seed	10 gm	10	L	for planting

TABLE 3.10. con't.

Scientific Name	Plant Part	Unit	Price/Unit	Habitat[a]	Uses
Indigofera arrecta	seed	30 gm	25	L	for growing indigo
Lagenaria siceraria	fruit	small: 10 cm	50	L	spoon
Lagenaria siceraria	fruit	large: 50 cm	1000	L	bowl
Lawsonia inermis	powdered of leaves & grain	60 gm	75	L	henna: colorant; muscle relaxant used for childbirth
Luffa aegyptiaca	fiber	30 gm	25	S	sponge, washcloth
Oryza sativa	unhusked grain	600 gm	100	L	food (rice)
Panicum anababtismum	stems	70 cm long	100	L	broom
Parkia biglobosa	powdered seed	250 gm	150	S	food
Parkia biglobosa	cooked seed	20 gm	10	S	food
Pterocarpus erinaceus	charcoal	1300 gm	100	L	fuel
Securidaca longiped.	twigs	77 gm, or 90 cm long by 1 cm wide	75	L	antivenom medicine
Strychnos spinosa	fruit	180 gm (one)	50	L	food
Tamarindus indica	fruit	64 gm-WW	25	L	food/medicine
Vigna unguiculata	bean	40 gm	25	L	food (black-eyed & grey cowpea)
Zingiber officinale	root	70 gm	50	S	food (ginger)

SOURCE: Survey data.

NOTES: [a]L = locally grown, S = grows in the south (wetter areas).
[b]WW = wet weight, DM = dry matter weight.

livestock. Therefore the allocation of water-points in the future should also consider the range types and availability of forage species.

People use the rangelands in many different ways, and the Bakel market offers a diverse supply of products, most of which are locally gathered or produced. It is recommended that a survey be conducted to measure the quantity of wood being used by the Bakel residents as well as other villagers for construction and fuelwood. This survey would be used to develop a reforestation program in the project zone.

3.3. LIVESTOCK MANAGEMENT AND PRODUCTIVITY

Based on previous project reports, on spontaneous interviews with livestock owners, herders and users, and on close observations of daily village life, it is possible to provide the following description of the livestock husbandry system among the Toucouleur of the project area. Data on the ownership and reproductive parameters of livestock were collected by the Socioeconomic Team and are included in their report (see Socioeconomic Study Report).

3.3.1. Cattle

As mentioned previously, cattle in the project zone are generally not herded except in two distinct cases. The first case is in the October/November camping season. At this time, the cattle are kept from returning to the village, and every other day one of herders returns to the village to deliver milk and to take back millet or sorghum meal. The herders are often young boys and men from the village who may be accompanied by a hired professional Peul herder from the Ferlo. As soon as all the harvest is in, the cattle are returned to the village to graze on the harvest residue. The professional herder is usually paid 10,000 FCFA a month in cash, and a sheep or goat.

The second case where cattle are herded is if they are forced to transhume south because of the lack of water in the dry season. In this case, the majority of the herd is entrusted to a professional herder who may stay away even until mid-July before returning the herd to the village. In the meantime a few of the milking cows and their calves are kept at the village.

There is no tradition of actively guiding the herd to specific pastures. The herder only makes sure that there are no straying or lagging cows. Otherwise, they feel that the cow "knows better than any human what is good for her." None of the herders interviewed would try to keep the herd off the degraded areas, or would try to steer them towards less used pastures. In any case, these professional herders are seldom hired for more than two

months, and they will herd the cattle to camps for only 2-4 weeks of that period. For the remainder of the time, they are usually told to work in the crop fields once they have milked and released the cattle every day.

For the rest of the year, the cattle are not controlled in any way. The task of the livestock owner is merely to milk and release the cattle from their stakes every day and to lead them in the different directions from the village at least once, so that the cattle become familiar with the terrain. Thereafter it is the lead cow that takes on the responsibility of "herding" the cattle. The system works very well for the cattle since they will minimize their losses and maximize their immediate gains. However, this usually means that rangelands suffer, and the Bakel area is no exception.

The institution of herding is more widespread among the villages in the Senegal Basin than in the Gambia Basin. The main reason is that there are more natural resources in the latter, and the cattle generally can find enough to graze by themselves. However, there are less resources in the Senegal Basin (especially in the northern, more degraded areas). Therefore in most cases there is a need for herders to accompany the cattle in order to cut down leafy branches or fruit that are out-of-reach of the cattle. Thus herding is only done at the last resort.

The people see other constraints to herding. Many say that it is hard work where the benefits are not apparent nor worth the while. In addition, year-round herding, especially during the rainy season, would take away labor that is needed for cultivation. Finally, the younger generation seems to be looking more toward Bakel and its modernity, than to herding as a profession. Yet, a rationalization of the livestock industry in the zone necessitates herding (or its more expensive alternative, fencing). The Range Management Plan, in Chapter 5 will elaborate on this idea.

The only other time that labor is expended on cattle, is during the dry season when the animals must be watered at the village well. A survey was done on the watering of livestock at two villages in the Mbaniou Zone in May 1984. A total of seven herds were monitored for two consecutive days at the wells. Because of the slow seepage of water into wells, the herds had to take turns at the well. At any point in time up to three herds were watered at the well. On the average it took two men, two hours to water 100 cattle, who consequently drank 26.71 litres of water per head per day.

The order in which each herd is watered at the well is established each year in December/January at a village meeting chaired by the village chief. However, at least in the village of Toulekedi, this order has not changed in the past 10 years. The order appears to be linked to the internal political hierarchy of the village. There are definite costs and benefits to one's position in the watering cycle. The herds watered in the

morning benefit the most since they then have the rest of the day to graze and can walk far from the village to relatively less used pastures. Those herds watered around noon are the worst off since they cannot graze too far neither in the morning nor in the afternoon. The herds watered in the afternoon and evening are better off than the noon herds since they can graze farther away, but they are not as well off as the morning herd since they have to graze on a thirsty stomach.

Each family has its own watering basin around the well. These basins traditionally were dug-out logs, but they are being replaced by oil barrels cut in half, or large brick and cement basins. The watering of cattle is done by young men from the family using a goat skin sack that can contain 10-20 litres of water and an iron pulley attached to wooden posts atop the well. If the family owns a horse or donkey, it will be used to pull the rope. Only the well itself is communally owned by the villagers.

Outsiders, especially nomads or other travellers, generally are not barred from using the wells, however, they must first ask permission from the village chief. Only one village in the project zone (excluding Bakel and Kidira) has a functioning motor-pumped deep bore-well. This well was petitioned by the villagers, and was built by the Government's Rural Works Services. The village charges 60 FCFA per month per head of cattle to the villagers, and 65-70 FCFA to livestock from other villages (400 FCFA are roughly equivalent to one dollar). In addition, there is a daily water cart that travels the main road as far as 20 km from the village. The water tank on the cart holds about 2500 litres of water, and the entire reservoir is sold at 31,000 FCFA to a village or group of villages The revenue from these sales is used to maintain the pump and diesel supplies. In no instance in the entire project zone was a fee charged for using a traditional, manually operated well.

During the early rainy season and continuing into August/September most herds traditionally receive a salt supplement. A small pit is dug near the village which the rains fill with water, and rock salt is added to it. All livestock then have access to this supplement, and most appear to appreciate it highly. Because of convenience, these pits are dug not even 500 m from the village well, which tends to aggravate the degradation problem around the village.

The people in general have a very intimate knowledge of their animals' needs and potentials. Some cows, chosen as favorites, are caressed and fed scraps from the family meal, or special hay. All cattle in the herd are given names. Table 3.11. provides a sampling of these names and their rough translation into English. The cattle are treated gently, but they are not quite as gentle as the livestock of nomadic people.

TABLE 3.11.

LIST OF SOME NAMES GIVEN TO CATTLE
BY THE TOUCOULEUR OF THE PROJECT AREA

Pulaar	Translation	Pulaar	Translation
Soyé	Grey color	Bigel	First calf of cow
Cajel	Red & white color	Goullal	Named after original owner
Gajel	Horns turned backwards	Hamadi padi	Named after a herder
Wogneré	Red & white faint black face	Jobolé	Vertical horns
Siwé	White with faint black stripes	Kibbal/loggu	Circular horns
Olel	Yellow color	Lajowal	Lame cow
Wigé gumalo	No horns	Machine	Draft ox
Wigé boy	White color	Kodda	Last calf of the cow
		Gnaki	Small red spots

SOURCE: Survey data.

The productivity of cattle can be measured through three indexes. The index that is most relevant to the people themselves is the amount of milk produced by the cow. A second index is the live-weight, and the third is the amount of manure that can fertilize fields. The socioeconomic team has surveyed the manure production, and the data are given in their report. The range manager had intended to measure the live-weight of cattle and its seasonal variation, however none of the weight-scales were in operational shape. It is recommended that the project design a survey to measure the live-weight of at least 100 cattle of varying ages and sex, and to correlate these with the breast-width of the animals. The regression equation that could be derived from this survey would be used to convert breast-width (which is easier to obtain) to live-weight. This technique would not only help future monitoring efforts of the livestock, but also could be used for establishing buying/selling prices for the commercialization program.

To measure the milk production by the cows, two complementary surveys were designed. The first involved the collection of milk samples from 10-12 cows in the Mbaniou Zone once every season in 1983/84. A preservative was added to these samples, and they were sent to the ORANA laboratory in Dakar for nutritional content analysis. Because of logistical problems there sometimes were delays of 3-5 days between field

collection and arrival at the laboratory. This may have affected the quality of the samples.

The second survey involved the measurement of milk extracted for human consumption. Because of logistical problems and cultural sensitivities, no attempt was made to measure the amount of milk that was consumed by the calf. The milk from each cow was measured using a plastic beaker, graduated to the nearest 50 ml, immediately after each milking, morning and night. The data were gathered on three consecutive days for the same cow. A total of 221 cows were studied during the survey, with an average of 44 cows per season. The age of each cow and her lactation period were recorded for each milking by asking the herder or herd owner.

Of the total sample of cows, 50 of them were monitored all year. Yet each time the herder would give slightly different and inconsistent ages for each cow or calf. Therefore it was not possible to analyze the data according to age of cow or lactation period because there was no confidence in the data reported by the herders.

Table 3.12. provides a summary of the nutritional analysis of the milk samples, and compares the results to other tropical and temperate regions. The data show that the milk in our project zone is of good quality, and generally even better than other Sahelo-Sudanian regions.

Unfortunately there was too much standard deviation around the means to allow a meaningful comparison of the seasonal differences of milk quality in the project zone. In addition it is not possible to compare the two samples from April 1984 (one is from cows that had received protein supplements, and the other from nonsupplemented cows). The total number of samples (12) is not enough to allow a statistical comparison from this survey. It is recommended that in the future, a milk quality monitoring program be implemented that would allow an evaluation of not only the seasonal variations in milk quality, but also of the effects of protein supplementation. The number of sampled cows should be at least 30 per season.

Table 3.13. provides the results of the milk quantity survey. The data on the plants eaten by the cows are obtained from the bite-count survey (see section 3.2.1.3.). The figures on the daily Digestible Crude Protein (DCP) required in the diet are obtained from IEMVT (1978). They represent the need for the maintenance of a 250 kg lactating cow. The estimated DCP available in the diet is calculated using the bite-count survey data, laboratory analysis of the woody species, and nutritional tables (IEMVT, 1978).

The data show that the quantity of milk extracted by people, as expected, is greatest in August, and least in May/June. Only 7% of the total sample of 221 cows gave more than 1.5 litres per day for human consumption, while the maximum quantity ever taken

TABLE 3.12.

AVERAGE NUTRITIONAL CONTENT OF COWS' MILK IN PROJECT ZONE, 1983/84, COMPARED TO OTHER REGIONS
(all figures in % of dry matter)

Source	Month	Humidity	Protein	Lactose	Fat	Ash
Gambia Basin	August 1983	86.99	3.97	5.55	3.16	0.762
Gambia Basin	February 1984	88.12	3.79	5.21	4.19	0.754
Gambia Basin	April 1984	84.97	4.63	5.38	4.70	0.806
Gambia Basin	June 1984	84.57	4.21	5.70	3.55	0.793
Gambia Basin	April 1984[a]	86.93	3.48	5.325	3.60	0.825
Ngok Dinka	May 1980[b]	89.4	3.10	?	1.80	?
Bor Dinka	July 1977[c]	76.4	4.10	?	4.3	?
Sahel Zebu Cow	End of dry season[d]	?	3.0	?	2.5	?
Temperate Cow	Staff-fed[e]	87.6	3.20	?	3.7	?

SOURCE: Survey data and literature.

NOTES: [a]Samples herd had received cotton seed as a supplemental feed.
[b]Data obtained from southern Sudan (Niamir, 1981: 124).
[c]Data obtained from southern Sudan (Payne, 1977).
[d]Data obtained from Dahl (1976: 154).
[e]Data obtained from Williamson and Payne (1978: 663).

off was 2.14 litres per day. On the average, assuming a lactation period of 12 months and accounting for seasonal variations, a cow can be expected to give 337 kg of milk for human consumption. The average milk yield (ie., including what the calf takes) in the tropics is roughly 630 kg per lactation (Williamson and Payne, 1978: 254). Therefore, it seems that the people on the project zone tend to extract a little more than half of the total milk yield per cow for human consumption. The need for supplemental feeding of lactating cows is clearly demonstrated.

3.3.2. Sheep and Goats

The small ruminants remain at the village all year, and at night are staked inside open-sided huts. There tend to be more goats than sheep in a household's flock. The small ruminants tend to graze together, and it is not clear which animal leads the others: goats tend to be in the front, but they wander around and scatter in the pasture, whereas the sheep, although in the back, tend to stay together, and move in a straight, determined direction, seemingly oblivious to the goats' wanderings.

TABLE 3.13.

RESULTS OF MILK QUANTITY MEASUREMENTS
1983/84

Date of Samples	Dominant Species in Diet of Cows	Average Quantity of Milk l/cow/day	Total DCP in Diet gm/day	Total DCP Required gm/day
August 1983	Diheteropogon Hagerupii Aeschynomene Schimperi	1.170	291	210
November 1983	Borreria stachydea Schizachyrium nodulosum	0.800	226	210
March 1984	Schizachyrium nodulosum	0.630	167	210
May 1984	Boscia senegalensis Lepidagathis anobrya	0.510[a]	157	210
June 1984	Boscia senegalensis Pterocarpus lucens	0.560[a]	157	210

SOURCE: Survey data.

NOTE: [a]May and June figures are not significantly different from each other.

The flocks may be accompanied by a herder only in the end of the dry season when forage is scarce or inaccessible. At this time, the herder's task is merely to follow the flock, and to cut down leaves or fruit pods of trees that they may come across. The trees that are cropped the most are Acacia Seyal and Balanites aegyptiaca. These species seem to regenerate very quickly in the following season. The fruit pods of Piliostigma reticulatum, Acacia nilotica and Pterocarpus erinaceus are the most sought after. The fruit of the baobab tree are also knocked down for the flocks.

During the rainy season the flocks water at small natural ponds that are found close to the village. They also lick the minerals in the salt pits mentioned previously. During the dry season, the task of watering the flocks is left to the women. They will provide water at the village compound from basins that they use to bring water for their family. The daily scene in a village at around noontime, is a virtual invasion of braying sheep and goats, who rush through the compound, upsetting pots and pans in their search for water.

About two months before Tabaski (a special Muslim holiday), every housewife will start to fatten a ram for the feast. These rams tend to become like pets, following the wife everywhere and eating leftover scraps from the family meal or fresh Pterocarpus lucens and Grewia bicolor leaves that are cut and brought to them.

There is a far greater amount of selling and slaughtering sheep and goats than cattle. This is mainly due to the fact that the small ruminants' meat is of far less quantity, and therefore does not need to be stored once it is slaughtered. In addition, the taste of small ruminants' meat (especially sheep) is preferred to that of the cattle. The small ruminants are not milked by people, unless the supply from the cattle is very low, and even then only when absolutely necessary. The reason most often given is that the small ruminants have very little milk yield and not enough would be left for the lamb or kid. The manure from small ruminants, which collects in their barns, is sometimes used for vegetable plots around the compound especially in villages along the Senegal and Falamé Rivers. These plots are often irrigated by hand and vegetables such as onions, tomatoes and jakhatou (a bitter, yellow-skinned eggplant) are grown in the cold season.

3.3.3. Horses, Donkeys, and Chickens

The few horses that exist in the project zone are cared for intensively by the owner. Eating food leftover from meals and salt, and having daily exercise and washing is common. Some villages have substantial donkey herds who, like horses, graze around the village. Both of these animals are normally hobbled (by tying their legs) so that they do not wander far from the village. Donkeys are the only animals that do not mind grazing at night.

Horses and donkeys are commonly used as draft animals for drawing carts, water from wells, or plows in fields. Some families who do not have donkeys or horses may hitch a pair of oxen, or even a cow to the plow. However, only the horses are ever given cut hay during the plowing season.

Every household has a few chickens and roosters. The poultry are of a local breed with long legs and necks. The women are the ones responsible for the poultry. However, apart from the construction of a coop, the poultry are basically left to fend for themselves. Eggs are rarely eaten or sold. The chickens are eaten during special occasions (eg., it is prescribed for women who have given birth) or given as gifts. The revenue from the sale of poultry goes to the women's purse however the men can give poultry away as gifts.

3.3.4. Interface with Farming

The livestock industry and management system is closely linked with the farming system in the project zone. The manure from the livestock is an important source of fertilizer for the fields. During the dry season the livestock are staked on the fields, and their location is changed every two weeks to spread the manure over all the field. However, this method is not as effective as it could be since it is only the urea that can penetrate the soil. The manure itself remains in large clods because the system of spreading the cattle on the field does not allow trampling and pulverizing of the clods. Thus the manure does not decompose easily and may take a few years before it is incorporated effectively into the soil. In some villages the people will burn the clods and remaining residue just before plowing time so that it does not impede the plowing or sowing. In this case, all of the nitrogen value and organic matter of the manure is lost through burning.

The neighbors of the Toucouleurs to the south, where soil fertility appears to be a greater constraint, tend to keep the cattle in one spot all during the dry season so that the manure is pulverized, and then will spread the powder over the fields and immediately plow it under. This method is much more effective. The people in the project zone should be encouraged to adopt this method even though it involves a greater labor expenditure.

Another problem is the fact that livestock are allowed to graze off the crop residue immediately after the harvest. The value of the residue at this time is equal to or even less than the value of the standing forage in the pastures. Therefore it seems that the only reason why the cattle are allowed into the fields is because the herders do not wish to remain in the bush camp any longer, and the fences around the fields are not maintained year-round.

Grazing the crop residue immediately after the harvest has two major problems. The first is that it leaves the field bare and without cover for the rest of the dry season, thus exposing the soil to wind erosion. The second problem is that of an opportunity lost. If the crop residue is left on the fields, the livestock will have access to a substantial quantity of forage when they need it the most: i.e., in April and May.

The cultivation system itself appears to cause a few problems as well. On the one hand there does not appear to be much of a fallow system. The fields around the village seem to be cultivated every year. The fields much farther away in streambeds may be left fallow but that appears to be due more to constraints imposed by a high water flow than to choice. A fallow system accompanied by a more effective manure utilization system may be more productive in the long run.

Finally, there is no system of plowing that follows the contour of the land. The slopes are very flat for the most part, however, in some steeper areas (i.e., those approaching streambeds) many cases of erosion were seen to be advancing into the fields. Contour plowing on these steeper areas may be effective in safeguarding against soil erosion.

3.3.5. Conclusions and Recommendations

The Toucouleur of the project zone maintain a very diverse portfolio of livestock designed to meet various needs. Cattle are kept mainly for their milk, as a source of wealth and recurring income (reproduction of calves). Small ruminants and poultry are raised primarily for their meat and as gifts and for other cultural transactions. Horses and donkeys are kept as draft animals.

However, the management of these livestock traditionally has not required much investment (whether capital or labor). The only substantial labor requirement is during the times that livestock are watered at the village well, and even herding does not require much labor. Therefore, compared to the cultivation system, very little time, labor and economic resources are spent on maintaining and exploiting the livestock.

As later sections will show, this lack of control over the livestock is a major cause of degradation of the rangelands in the project zone. Various simple changes in the management system are proposed in the Range Management Plan that could help prevent further environmental degradation. Contour plowing of steep areas on the fields, a longer fallow period, and a more efficient crop residue/manure exchange between cattle and the fields, would help to increase the productivity of the cultivated lands.

It is recommended that two monitoring programs be established by the project on the productivity of the livestock. The first is a live-weight monitoring system and the second

is a milk quantity/quality monitoring system. Both systems would be used for ongoing evaluation and feedback on the project's impacts (especially the supplementation and commercialization programs).

3.4. RANGE PRODUCTIVITY

The research on range productivity had as a major objective, the study of the dynamics of the vegetation community, in terms of both the ecology and exploitation (by livestock and people). Unfortunately, the range manager did not have the means to measure the productivity of the woody species. This produced a major problem for the calculation of stocking capacities, which will be discussed in section 3.5. Therefore, this study of range dynamics concentrates entirely upon the herbaceous stratum.

The range manager had the opportunity to observe the rangelands in two consecutive rainy seasons. This produced many answers, but it also raised more questions for a future researcher.

3.4.1. Biomass Studies

Biomass studies on the herbaceous vegetation of the rangelands were carried out on the same sites in three points in time (September 1983, May 1984 and September 1984). These represent the biomass existing on the range at the end of the growing season (September) and the end of the dry season (May). Strictly speaking, they do not represent the net productivity of the plant community under grazing conditions during the rainy season. However, biomass studies do provide an indication of the availability of forage in the dry season.

The methodology consisted of placing ten $0.5m^2$ circles 20 paces apart on the sample site, and cutting all standing biomass at stubble height (1-2 cm off the ground). This standing biomass was divided (in the field) into two plastic sacks, one for monocots (grasses and sedges) and the other for dicots (all other herbs). Two other sacks were filled with herb or woody litter. All sacks were then oven-dried at 80°C (using either a solar oven or a gas oven) and weighed.

3.4.1.1. Biomass per hectare

~~Both 1983 and 1984 September data show a lot of variability between the range types~~ (see Table 3.14). The streambed range type in the Gambia River Basin supports the greatest amount of biomass in September than all other range types. In addition, the data show that the streambed range type did not change significantly in 1984 compared to 1983, even though the rainfall in the project zone was less. This is understandable given the concentration of water and the deep clay loam soils in these areas.

TABLE 3.14.

SUMMARY OF BIOMASS STUDIES
(all figures in kg-DM/ha)

	Range Type	Ironstone	Floodplain (G)	Floodplain (S)	Degraded (G)	Degraded (S)	Hill	Foothill	Streambed (G)	Swamp	Average Gambia Basin[a]	Average Senegal Basin[a]
Sept 1983:	monocot	3040	1263	2347	69	203	1692	2703	2113	1058		
	dicot	460	622	107	65	488	142	265	1129	1021		
	total	3500	1885	2454	134	691	1834	2968	3242	2079	2168	1987
	% monocot	%87	%67	%96	%51	%29	%92	%91	%65	%51		
May 1984:	total herb	720	818	616	0	0	425	1399	1577	b	779	610
	% change from 09/83	-79	-57	-75	-100	-100	-77	-53	-51	b		
	woody litter	280	194	72	0	0	304	T	321	b	199	94
Sept 1984:	monocot	970	768	1515	34	39	500	439	1589	1779		
	dicot	181	207	170	51	41	135	318	412	71		
	total	1151	975	1585	85	80	635	757	1981	1850	1208	764
	% monocto	%84	%79	%96	%40	%49	%79	%58	%80	%96		
	% change from 09/83	-67	-48	-35[c]	-37[c]	-88	-65	-74	-39[c]	-11[c]		

NOTES: [a]Not weighted averages.

[b]All sites had been burnt.

[c]Not a significant difference.

The ironstone plateau is probably the next range type in terms of total biomass, however it is very sensitive to yearly rainfall amounts. The same sensitivity is apparent in the hill and foothill range types. This is probably due to the fact that these range types have coarser soil and/or shallow soil profiles, resulting in lower water-holding capacities.

The swamp range type and degraded areas are pretty much insensitive to rainfall changes but for different reasons. The swamplands like the streambeds normally hold more water. A reduction in yearly rainfall probably translates into a relatively smaller reduction in water availability to the plants. On the other hand, the plants that grow on the degraded areas are hardy species that are already adapted to low moisture conditions, and appear to be less affected by variations in annual rainfall.

As expected, both of the floodplain range types show smaller changes in biomass between 1984 and 1983 than the ironstone or hill range types. This is because the soils are deeper and finer than in the hilly areas.

A comparison of the percentage composition by weight of monocots in all range types shows that, as expected, the wetter areas with finer soils (streambed and swamp) have less monocots, while areas with coarser soils (ironstone, foothill, hill) have more monocots. The floodplains fall somewhere in-between. Surprisingly, degraded areas have the least percentage of monocots. This is probably due to the fact that the few dicots that persist on degraded areas are large and stemmy species (eg. Cassia Tora or Sida stipulata).

A comparison of 1983 and 1984 data suggests that as expected a drier year generally tends to encourage more monocots. However, this was not true for the foothill range type which saw a decrease in monocots. This was probably due to an increase in Zornia glochidiata, which is generally considered to be an invader of degraded sandy soils. In addition, the percentage of monocots did not change significantly in ironstone, degraded and hill areas, probably because, as before, the few dicots that do persist here, are hardy plants.

The biomass loss during the 1983/84 dry season is strikingly high across all range types. All range types show losses greater than the theoretical 50% PUF (proper use factor) required for soil protection. The difference between September 1983 and May 1984 represents a loss of biomass primarily due to grazing (livestock and wildlife), wind damage, and insect damage (it does not include destruction by fire; this is discussed later). Unfortunately it was not possible to monitor all sites in order to separate the causes. However, one site in the Gambia floodplain range type can safely be considered to have not been used by large mammals during the dry season (this was verified by searching for fecal matter in a 100 m^2 area, and by searching for evidence of

trampling). In this site (V6) the biomass loss was almost 78% compared to September 1983 (see Appendix A.). The major part of this loss is probably due to consumption by termites. Without more detailed studies it is impossible to assess the exact role of termites in rangeland forage consumption. However, it is clear that termites, especially in the dry season, are a major competitor to livestock for forage. It would be totally unrealistic, as some people have suggested, to think about a termite eradication campaign. Not only would it be a logistical nightmare but also, the positive aspects of termites in the ecology cannot be ignored. Termites help the ecological cycle by speeding up the decomposition of organic matter. They help in "plowing" the soil by bringing up clay and silt from the subsoil and depositing it on the surface. Another positive aspect is that Boscia senegalensis, a nondecidious bush that provides much needed protein and minerals for all livestock during the dry season (see section 3.2.1.3.), tends to grow almost exclusively on termite mounds.

In May 1984 the biomass collected from the sites were divided into standing (rooted) herb, herb litter and woody litter (fallen leaves, flowers and fruit). (See Appendix A.) The relative weights of standing herb to litter herb may suggest the degree of utilization (trampling) of the site by large mammals. The only site with a higher percentage of standing herb was V6. All other sites had more litter than standing biomass. It was observed during the bite-count survey (section 3.2.1.3.) that during the dry season, there is high consumption of litter by all livestock. This was also observed for woody litter. In fact, livestock will tend to congregate around special trees that bear high quality fruit. In addition, when cattle cross a burnt area, they do not hesitate to browse on the singed leaves of Combretum glutinosum. (This is probably the only time that Combretum glutinosum is browsed, since the leaves contain an oily, bitter substance when green.) Therefore, much of the biomass of woody species and litter is regularly consumed by livestock.

3.4.1.2. Bush fires

Apart from termite damage and drought, bush fires are another important factor in the reduction of biomass during the dry season, and they may even affect its productivity.

A manual interpretation of the December 1977 Landsat (satellite) image of the project area shows that 56% of the Gambia Basin and 49% of the southern part of the Senegal Basin had already been burnt. (The northern part of the Senegal Basin is almost 50% denuded and the incidence of fire is therefore low, 13%.) Another technique used to estimate burnt areas is a "road survey." The presence of firebreaks in the zone allowed access into almost all parts of the Gambia River Basin area. The odometer on the vehicle is then used to measure the percentage of road-length that is burnt. This technique was done by Dickie (1982: 42) and Niamir (1984). The results are presented in Table 3.15.

TABLE 3.15.

PERCENT OF ROAD LENGTH BURNT IN
GAMBIA RIVER BASIN AREA
1979-1984

	1979[a]	1980[a]	1982/83[b]	1983/84[b]
Length of road surveyed (km)	211.0	211.0	50.0	230.0
Percent burnt	47%	49%	70%	49%

SOURCE: [a]Dickie (1982);
[b]Survey data.

Even though we only have sampled data, the figures suggest that a very high percentage of rangelands are burnt every year. Most of the bushfires start as soon as the rains stop (in early October sometimes). The winds are normally southwest at this time and most fires are "back-burning" ones. These early fires are less destructive since most herbaceous species are still green (especially the dicots) and the burn tends to be patchy. But most of the fires occur in the November-January period when all herbs are brittle and dry. These fires tend to be very strong and may last 2-3 days covering many hectares. A few small fires were observed in the February-May period in 1984, but they do not last long mainly because a major portion of the biomass has already been burnt.

Various reasons have been given for these bush fires. The most important appears to be honey-gathering (which is done by smoking the bees out of their hives). Another reason is hunting parties which traditionally are held after the harvest in December. These parties sometimes use fire to smoke out the deer. Finally, the campsites where cattle have been staked for 2-4 weeks are burnt both before camping (to reduce the brush) and after (to kill off ticks and other parasites). Some of these fires may accidentally spread.

There are both advantages and disadvantages to yearly burning of an annual herbaceous community. These are presented in Table 3.16. Penning de Vries (1982) provides a more detailed review of these effects. Note that if the Project Area had had more perennial grasses then there would have been the added benefit of fresh, green regrowth from these plants.

In rainy season of 1983 and 1984 it was possible to take a closer look at the effects of fire on the ecology of the area. One site was found, on sandy soils of the foothill range type, that was known to have been burnt on one side (north) of the road for the past two consecutive years, while the other side (south) had not been burnt. Observations on both sides showed that the soils were similar, and that the grazing pressure was similar. The

TABLE 3.16.

ADVANTAGES AND DISADVANTAGES OF YEARLY BURNING ON ANNUAL HERBACEOUS COMMUNITIES

Advantages	Disadvantages
1. Reduces accumulation of litter which may impede germination, and may result in stronger fires that would burn more trees.	1. Loss of organic matter, nitrogen and sulfur with a corresponding loss of up to 15% in the next year's biomass (as estimated from models. See Penning de Vries, p. 352).
2. Makes the ash (phosphorus, potassium, magnesium and calcium) more readily available to the plants.	2. Increase in evaporation of soil moisture due to reduction of cover.
3. Reduces ticks and parasites.	3. More susceptibility to wind and water erosion due to loss of cover.
4. In some cases, encourages more desirable plants to dominate.	4. A greater homogeneity in the plant community (which may or may not be desirable).

tree and shrub layer were counted (density) while the frequency-biomass method was used on the herb layer. Unfortunately, we cannot extrapolate much more than two years from these data because their "fire history" before 1983 is not known. It is known, only, that in January 1974, December 1977 and March 1980 (when remote sensing data are available) the north side had been burnt, and the south side had not.

The changes in the vegetation community of the two sides are apparent in wet season 1983, but they are much more prominant in 1984. A comparison of the two sites shows the following significant points:

- higher relative frequency of grasses in the burnt area (84% grasses in burnt vs. 50% in nonburnt -- however, there was also a reduction in *Cenchrus bifloris* in burnt area);
- reduction in legumes in burnt area (especially *Zornia glochidiata*);
- reduction in herbaceous species richness;
- reduction of up to 20% in total herb biomass in second year in burnt area (possibly compounded by reduction in rainfall) most of this is reduction in dicot biomass;

- reduction in tree species richness (burnt area was 34% of nonburnt);
- reduction in tree and shrub density in burnt area (-24%);
- a relative reduction of trees, and a relative increase of bushes (esp. Guiera sensegalensis) in burnt area.

It appears that on sandy soils, yearly fire tends to encourage Guiera senegalensis and some grasses, while discouraging trees and legumes. On loamy soils it was not possible to find a suitable research site. However, a subjective evaluation shows the main difference between loamy and sandy sites to be a relative increase of the bush Combretum glutinosum. Otherwise, the same increase in grasses and reduction in legumes is also observed.

The data are not totally definitive, but they tend to show that yearly fires create a change in the vegetation community that would probably favor the cattle, but certainly not the sheep or goats, nor probably, the ecology. However, technically, it probably would be advantageous to burn the pasture at regular intervals (3-5 years). More studies are needed to determine the most beneficial fire treatment. The problems involved in regulating and controlling the fires are discussed in Chapter 4.

3.4.1.3. Conclusions

In conclusion, it must be emphasized that the pastures in the project area are annual herbaceous communities of fairly moderate total biomass which have a good floral mixture of palatable species, especially a wide range of native legumes. They generally have a good tree and shrub density, also of high palatability. This makes the rangelands suitable to a wide range of domestic and wildlife animals. However, the pastures are highly susceptible to termites, droughts and fires. This makes the availability of forage quite variable and nearly uncontrollable not only over time, but also in its distribution over space.

3.4.2. Forage Nutritive Quality Analysis

We are fortunate nowadays of seeing much laboratory analysis of the nutritional quality of tropical feed. These have been published in at least three major books: FAO (1981), IEMVT (1978), and Bogdan (1977). The detailed analysis of the quality of pasturelands is ultimately useful for evaluating the feed intake of livestock.

The general situation in the project zone, as elsewhere in the Sahel, is characterized by a relatively high quality feed intake during the wet season, followed by very low quality feed during the dry season. The live-weight and milk production of cattle are very much affected by this recurrent cycle, whereas sheep and goats, because of their greater

consumption of woody species, do not go through the same extremes and maintain their live-weight relatively constant year-round.

The situation for the cattle in the dry season, as bad as it may look, is not totally disastrous. During the bite-count survey it was observed that cattle will increase their consumption of fruit pods of trees as of December. This includes scavenging for baobab fruit in competition with sheep, goats and monkeys. In addition, the leaves of the nondecidious Boscia senegalensis are a major part of the diet all during the dry season, and as young shoots of trees such as Pterocarpus lucens become available in April/May they are also consumed. The livestock continue to lose weight in the dry season, but probably at a slower rate than if they did not have this browse. Finally, cattle and small ruminants may spend 15-30 minutes each day licking salty bedrock that becomes exposed in eroded areas.

Another crucial period is the "July Crisis." During this time, the first rains arrive to wash away most of the standing hay and deposit them in thick mats in the stream beds. It may then take one to two weeks for the new grasses to grow high enough to be grazed. During this time, the livestock consume tree shoots and 4-5 species of bulbous plants (Crinum pauciflorum, Asparagus Pauli-Gulielmi, Dipcadi longiflorum), which are high in protein content, but relatively low in fibre and bulk. This probably translates into higher milk production but not any visible weight gain. In addition, the incidence of bloat is increased because the livestock may consume young legume shoots (esp. Cassia Tora).

Table 3.17. provides some calculations on the quality of feed in the diet of cattle and goats. Digestible Crude Protein (DCP) is an index that is sensitive to seasonal variations. The calculations show that on the average both cattle and goats consume a ration that has high DCP content during the rainy season. This DCP content is equal to the theoretical need for lactating goats. Cattle receive more than that necessary for maintenance and lactation, but less than that needed for a 100 gm/day growth in live-weight.

With the beginning of the dry season, the DCP consumed decreases but is still above what is required to maintain a lactation animal. After January until the end of the dry season, the cows consume less and less DCP, losing their rainy season weight and almost reaching their bare maintenance requirement. Therefore, the cows that continue to lactate in the dry season, are probably losing even more weight. The goats, on the other hand, consume enough to maintain their weight while lactating all during the dry season.

Samples of leaf matter from eight wood species were collected in June 1983 (end of dry season) and analyzed by the physicochemical lab of LNERV in Dakar. The results are presented in Table 3.18. The Total Digestible Nutrients (TDN) for Combretum glutinosum and Guiera senegalensis appear to be very high. This is due to the very high oil content of

TABLE 3.17.

DAILY DIGESTIBLE CRUDE PROTEIN (DCP) REQUIREMENTS AND AVAILABILITY IN DIET OF CATTLE AND GOATS - 1983 (all figures in gm DCP/day)

Type of Livestock	Requirements[a]			Availability[b]			
	Maintenance	Maintenance +1 kg milk produced per day	Maintenance + 100 gm/day growth + 1 kg milk per day	July-Sept[c]	Oct-Dec	Jan-Mar	Apr-June
Cattle (250 kg cow)	150	210	355	291	226	167	157
Goat (50 kg)	50	100	205	202	109	108	95

SOURCE: Survey data and literature.

NOTES: [a]Requirements were derived from IEMVT, 1978.

[b]Assume a total consumption of 6 kg dry matter/day/cow and 2 kg DM/day/goat all DCP values are averages for the season, and are derived from the bite-count survey.

[c]Assume rains start in July.

TABLE 3.18.

NUTRITIVE ANALYSIS OF EIGHT WOODY SPECIES IN PROJECT ZONE
(June 1983)

Plant and its Parts	Percent of dry matter											
	% Moisture	Organic Matter	Crude Protein	Crude Fiber	Ether Extract	NFE	Ash	Silicates	Calcium	Phosphorus	Magnesium	Potassium
Acacia seyal (young leaves)	63.03	93.88	20.3	12.29	2.42	58.87	6.12	0.28	0.8	0.24	0.26	1.61
Adansonia digitata (young leaves)	64.03	89.92	15.25	15.81	2.68	56.18	10.08	0.51	2.16	0.23	0.58	1.90
Balanites aegyptiaca (young leaves)	65.82	89.01	19.15	21.18	--	--	10.99	0.47	1.84	0.17	0.57	3.23
Boscia senegalensis (old leaves)	35.47	90.14	16.22	26.08	1.67	46.17	9.86	2.87	0.99	0.06	0.72	0.88
Combretum glutinosum (young leaves)	58.54	94.15	10.42	22.54	13.30	47.86	5.85	0.35	0.85	0.2	0.51	1.24
Guiera senegalensis (young leaves)	72.52	94.21	20.33	22.58	2.97	48.33	5.79	0.52	0.73	0.27	0.30	1.23
Pterocarpus lucens (young leaves)	59.48	94.16	21.32	21.54	2.00	49.3	5.84	0.2	0.89	0.18	0.42	1.24
Ziziphus mauritiana (young leaves)	68.72	92.77	23.4	12.54	1.3	55.53	7.23	0.45	0.99	0.31	0.35	2.2

TABLE 3.18. (con't.)

Plant and its Parts	Parts per million					Soluble % Nitrogen	Disgestible Crude Protein %[a]	Total Digestible Nutrients %[b]	Metabolisable Energy kcal/kgDM[c]	UF per kgDM[d]
	Copper	Zinc	Cobalt	Manganese	Iron					
Acacia seyal (young leaves)	6.7	38.7	--	55.3	1219.1	13.66	15.8	62.1	2.21	0.67
Adansonia digitata (young leaves)	18.0	42.3	--	119.5	1964.0	12.7	10.75	45.36	1.61	0.35
Balanites aegyptiaca (young leaves)	9.1	20.[illegible]	--	120.1	2415	--	14.65	?	?	?
Boscia senegalensis (old leaves)	18.5	143.6	3.7	789	692	46.67	11.72	32.16	1.14	0.09
Combretum glutinosum (young leaves)	8.1	23.7	0.45	201.1	741.9	23.15	5.92	92.34	3.29	1.26
Guiera senegalensis (young leaves)	15.6	38.6	3.38	463	1798	21.78	15.83	54.75	1.95	0.53
Pterocarpus lucens (young leaves)	9.8	38.3	--	234.6	288.5	15.58	16.82	50.59	1.80	0.45
Ziziphus mauritiana (young leaves)	9.6	41.6	--	108.1	376.6	39.36	18.9	51.43	1.83	0.47

TABLE 3.18. (con't.)

NOTES: a) Digestible Crude Protein is derived from IEMVT (1978, p. 432):

$$\% \text{ DCP} = \%\text{CP} - 4.5$$

b) Total Digestible Nutrients is derived from IEMVT (1978, p. 433):

$$\begin{aligned}\% \text{ TDN} = & -202.686 - 1.357\,(\text{CF}) + 2.638\,(\text{EE}) + 3.003\,(\text{NFE}) + \\ & + 2.347\,(\text{CP}) + 0.046\,(\text{CF})^2 + 0.647\,(\text{EE})^2 + \\ & + 0.041\,(\text{CF})\,(\text{NFE}) - 0.081\,(\text{EE})\,(\text{NFE}) + \\ & + 0.553\,(\text{EE})\,(\text{CP}) - 0.046\,(\text{EE})^2\,(\text{CP})\end{aligned}$$

c) Metabolisable energy (mcal) is calculated as:

$$\text{ME (Mcal/KG)} = \frac{\text{TDN g/kgDM} \times 3.56}{1000}$$

d) <u>Unité fourragére</u> is derived from IEMVT (1978, p. 439):

$$\text{UF per KgDM} = \frac{[(\text{TDN g/kgDM})3.65] - 1000}{1883}$$

both species which makes them relatively less preferred. But they are apparently not toxic and will be consumed by all livestock if there is no other alternative. Boscia senegalensis has the highest trace mineral content which is surpasses only by Balanites aegyptiaca's iron content. Adansonia digitata and Balanites aegyptiaca both have high macromineral contents especially calcium and potassium (the leaves of these two species are also eaten by people).

Table 3.19. provides a comparison of the theoretical daily mineral requirements of cattle and goats in the tropics (McDowell, 1983) and the availability of minerals provided by the sampled browse in the dry season. Assuming that only browse provides significant amounts of trace minerals in the dry season, the table shows that cattle are probably deficient in all macroelements, as well as in copper and zinc. Goats appear to be deficient in phosphorus, potassium, copper and possibly magnesium.

3.4.3. Community Productivity Studies

The previous studies, biomass and nutritive quality, indicate the productivity of the rangeland in one static point in time. However, the herbaceous community all during the wet season is in a dynamic state of production and decay where nutrients are converted into new plant cells while cells in old leaves, roots and other plant parts die and decompose. In addition, grazing may result in a stimulation of renewed growth, in some cases surpassing the growth of nongrazed plants. Therefore, it is useful to evaluate the net primary productivity (NPP) of the rangeland (that is, the chemical energy stored after losses through respiration).

The technique chosen to evaluate NPP, the clipping study, is a crude but simple method. This technique does not exactly measure the NPP, but it does evaluate the effect of grazing, as simulated by manual clipping of the plants. Recommendations obtained from the clipping studies can be used as guidelines for rangeland use; however, they must be taken with caution since they cannot take into account all of the factors involved with grazing, such as trampling and uprooting, the action of saliva on plant cells, nonuniform cutting of plant stand, selective grazing, etc.

The five clipping studies done in the rainy season of 1983 were intended to simulate the effects of continuous grazing at different intensities. The two clipping studies done in 1984 were meant to reflect discontinuous or rest-rotation grazing. The clipping studies were done on the three major range types in the Gambia Basin (ironstone, floodplain and streambed), on the foothills range type of the Senegal Basin, and on a stand of Andropogon gayanus which may be found, albeit rarely, on both sides of the continental shelf.

TABLE 3.19.

DAILY MINERAL REQUIREMENTS AND AVAILABILITY IN BROWSE FOR LIVESTOCK IN THE DRY SEASON - 1983

Type of Livestock		Macroelements						Microelements		
		percent of dry matter						parts per million		
		Ca	P	Mg	K	Cn	2n	Co	Ma	Fe
Cattle[c] =	mineral content of browse ration[a]	0.29	0.05	0.12	0.42	3.0	12.1	0.6	60.1	273.0
	mineral need[b]	0.43	0.31	0.18	0.8	10.0	40.0	0.1	40.0	50.0
	percent of need met by browse	67%	16%	67%	53%	30%	30%	600%	150%	546%
Goats[d] =	mineral content[a] of browse ration	0.35	0.06	0.14	0.5	3.6	161	0.8	78.4	356
	mineral need[b]	0.16	0.1	?	0.6	5.0	35.0	0.1	25.0	100.0
	percent of need met by browse	218%	60%	?	83%	72%	460%	800%	314%	356%

SOURCE: Survey data and literature.

NOTES: [a]For cattle, the calculations are based on a diet compostiion of 25% browse and for goats 30% (see bite-count survey).

[b]The mineral needs are daily requirements derived from McDowell (1983) and IEMVT (1978).

[c]Figures are for a 250 kg lactating cow.

[d]Figures are for a 50 kg lactating goat.

The clipping sites were located in low use areas so that the potential productivity could be evaluated. Observations were made of the newly germinating plants and still-visible seeds, in order to verify the exact location of each site. These sites were then marked and a 2m x 1.5m area was fenced off just before the rains. Inside the plots, 24 equal-sized squares of 900 cm^2 (30 cm x 30 cm) were marked off by ironstakes (rebar) and fine wire (see Figure 3.4).

There were a total of five treatments in each plot. Each square was assigned to the treatments using a random-table, so that there were adequate replications to account for normal variations in the community. The treatments for all studies are presented in Table 3.20. and illustrated in Figure 3.4.

TABLE 3.20.

1983-84 CLIPPING STUDIES AND TREATMENTS

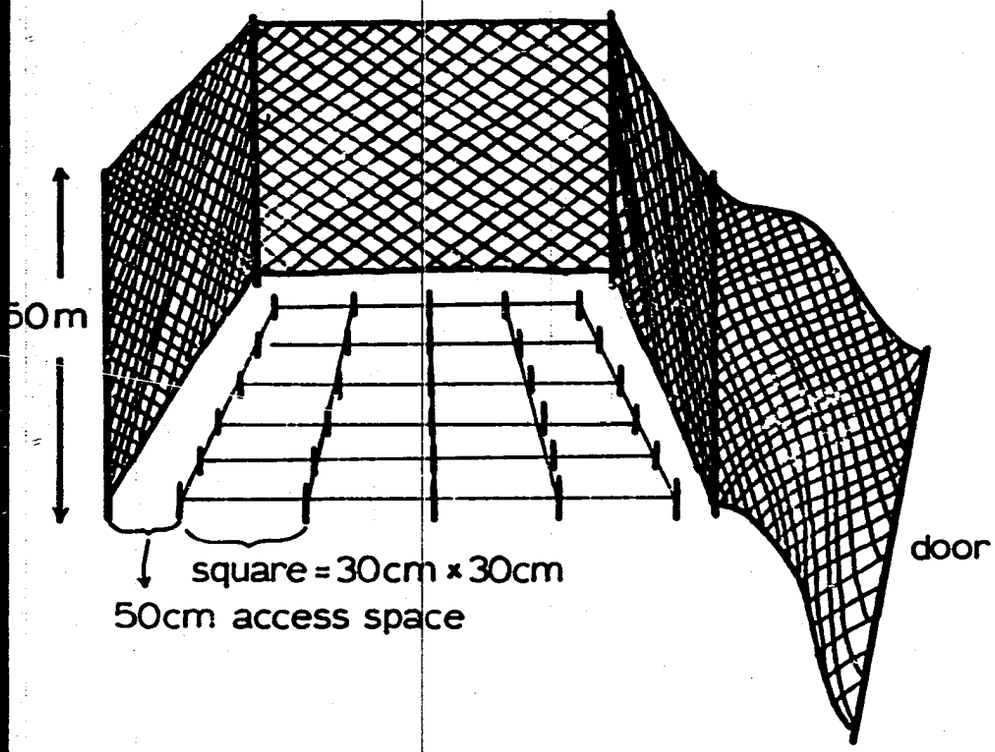
Treatment	1983 (continuous)	1983 (discontinuous)
1	cut 90% every month	cut 50% every month
2	cut 75% every month	cut 90% once in early vegetative stage
3	cut 50% every month	cut 90% once in mid-vegetative stage
4	cut 25% every month	cut 90% once in flowering stage
5	no cut	no cut

SOURCE: Survey data.

After each cut, the plants were divided into monocot and dicot piles, dried and weighed separately for each square. A final cut was done at the end of the growing season (beginning of dry season) in all squares at stubble-height, and dried and weighed accordingly. Wherever possible, the plants were divided into individual species piles. The cuttings during the rainy season, when added together, reflect the rainy season productivity. These can be converted directly into a stocking rate using 9 kg of forage/UBT/day or 1080 kg/UBT/wet season (UBT = Unité Bovin Tropical equivalent to a 250 kg cow and her calf). The cutting at the beginning of the dry season reflect the total amount of forage leftover for the dry season. Its stocking capacity is calculated as 2124 kg/UBT/dry season, using only 50% of the remaining forage.

Table 3.21. provides a summary of the results. The following pages give the detailed analysis for each range type studied.

FIGURE 3.4. Schematic Diagram of Clipping Study Site and Plant Cutting Intensity



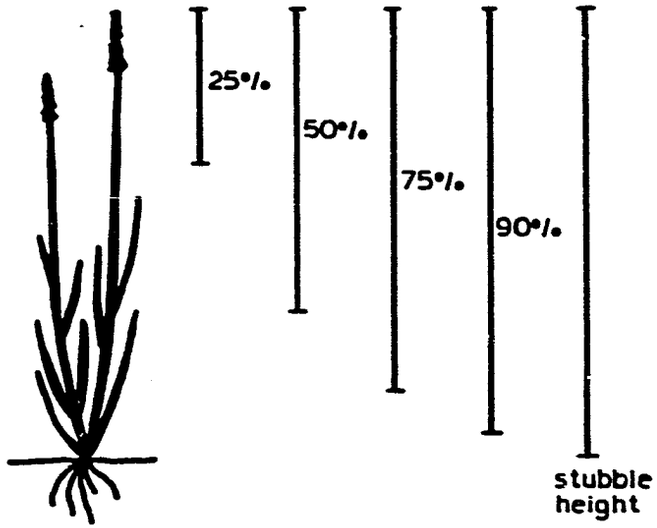


TABLE 3.21.

ESTIMATED STOCKING RATES AND CAPACITIES FROM CLIPPING STUDIES
(all figures in hectares/UBT per season or year)

Range Type	1983 Treatments					1984 Treatments				
	1	2	3	4	5	1	2	3	4	5
Ironstone W[a]	0.57	0.77	1.51	3.97	0	1.91	4.23	2.6	2.28	0
D[a]	11.84	2.79	1.82	2.09	1.92	2.23	1.11	1.98	2.61	1.31
All Year	1.58	1.49	1.7	2.48	2.85	2.11	1.46	2.15	2.49	1.96
Floodplain W	0.61	0.49	0.56	1.11	0	0.75	1.56	1.91	1.15	0
D	13.16	7.0	2.71	1.37	0.76	3.7	2.69	2.31	1.45	0.36
All Year	1.69	1.3	1.2	1.28	1.13	1.62	2.17	2.16	1.34	0.54
Streambed W	0.43	0.46	0.54	0.74	0					
D	30.5	4.19	1.04	0.37	0.19					
All Year	1.27	1.15	0.8	0.45	0.28					
Foothill W	0.62	0.61	0.99	2.55	0					
D	28.82	2.33	3.57	1.34	1.01					
All Year	1.81	1.21	1.93	1.59	1.51					
And. Gay[b] W	0.55	0.87	0.15	0.44	0					
B	10.4	225.0	477.5	657.2	1553.78					

NOTES: [a]W = wet season (120 days); D = dry season (245 days)

[b]Only the results from the Andropogon Gayanus stands are reported, not all biomass. "B" refers to gm DM/m^2 biomass of Andropogon Gayanus left over at the end of the season.

3.4.3.1. Ironstone plateau

The 1983 study showed that this is the only range type that has a higher total productivity if it is heavily used during the wet season. A continuous 75% treatment not only favored total biomass, but also a relative increase in dicots and the "sweet grasses" (such as Schizachyrium nodulosum). The 1984 study showed that this heavy use is most beneficial if it comes early in the vegetative stage of the plant community. The two studies may be taken to show that a recommended use of the ironstone range type would be heavy use in the wet season (on the order of 0.7-1.5 ha/UBT/120 days) preferably concentrated in July, and a moderately high use in the dry season (1.8-2.8 ha/UBT/245 days). This is mathematically equivalent to a potential capacity of 1.5 ha/UBT/year. The average biomass outside the fenced plot at the beginning of the dry season 1983 was 1794/kg/ha, which is roughly equivalent to the 25% use plots during the wet season in the clipping studies. This suggests that the ironstone range type, on the average, is being underutilized at present in the wet season.

3.4.3.2. Floodplain (Gambia)

This range type appears to be very sensitive to cutting during any part of the wet season. Even a low continuous cut (25%) results in significantly lower total biomass and total dicot. However, a low use appears to favor a relative increase in grasses. In any case, in both 1983 and 1984, the biomass available at the beginning of the dry season, as well as total yearly biomass is greatest if this range type is not used during the wet season. If this recommendation is followed, the pastures can be stocked at a rate of 0.7-1.0 ha/UBT/245 days of the dry season, or a mathematical potential capacity of 1.1 ha/UBT/year. The average end of season biomass outside the fenced plot was 1806 kg/ha in 1983, which is equivalent to a 50% use in the clipping studies. This figure suggests that this range type is currently overutilized during the wet season. This finding is confirmed by the fact that virtually all of the denuded lands in the Gambia Basin were originally of the floodplain range type.

3.4.3.3. Streambed (Gambia)

The streambed range type is the most productive area in the project zone. It produces highly palatable grasses as well as trees and shrubs. Yet it effectively covers only 0.3% of the Gambia River Basin. The clipping study done in 1983 shows that the highest total biomass was obtained with no use in the wet season. Low to no use in the wet season also favored the legumes and other dicots. If this recommendation is followed, the range type can be stocked as high as 0.2 ha/UBT/245 days of the dry season.

Mathematically this is equivalent to 0.3 ha/UBT/year. The average biomass outside the fenced plot at the beginning of the dry season was 4925 kg/ha, which is equivalent to a 25% use during the rainy season in the clipping studies. This suggests that the streambeds are currently being overutilized in the wet season.

3.4.3.4. Foothill

This is the only range type studied in the Senegal Basin. The 1983 clipping study does not show as clear a gradation as it does in the other range types. However, it suggests that a heavy continuous use in the wet season tends to favor an increase in total biomass and in grasses, while reducing somewhat the biomass of dicots. Considering the role of this range type in all of the project zone, it should probably be used in the wet season (0.5 ha/UBT/120), and the dry season (2.3 ha/UBT/245 days) This gives a mathematical equivalent of 1.2 ha/UBT/year. The average biomass outside the fenced study plot in September 1983 was 2634 kg/ha, which is equivalent to a 25% use in the clipping studies. This suggests that currently the site is underutilized in the wet season.

3.4.3.5. Andropogon Gayanus

This clipping study was intended to study the productivity of the perennial grass Andropogon Gayanus. In all of the project zone there remains only rare patches of this species in well-watered areas such as streambeds and the foothills (the latter have sandy soils over clay that retain relatively more soil moisture). The clipping study was intended to show the productivity of this species while in competition with annual species. The results only presented the biomass of the Andropogon Gayanus. They suggest that a moderately high (50%) continuous use of this plant during the wet season allows a relatively high stocking rate (0.15 ha/UBT/120 days) which results in less standing biomass at the end of the wet season, and relatively more regrowth during the first part of the dry season. This is understandable since the mature stand normally has tall, fleshy stems (as high as 2m) which, if left impedes the vigor of regrowth. The act of burning the stand beginning of the dry season would probably have similar if not better regrowth.

It appears that a good management strategy would be to use the Andropogon Gayanus heavily in the wet season, and then either cut the mature standing hay (it makes good roof-thatch) or burn it, in order to allow cattle access to the grass regrowth.

3.4.3.6. Conclusion

All of the clipping studies seem to suggest that the livestock should not be allowed to use the floodplain and streambed areas during the wet season and instead, should be taken

to the ironstone and foothill areas, which incidently are less prone to compaction than the loamy soils of the floodplains. With the advent of the dry season, livestock could be allowed back into the floodplain and streambeds again. The results from the Andropogon Gayanus study are slightly inconsistent with this conclusion since the Andropogon Gayanus stands also occur in the streambeds. In the final analysis, it is best to forage any benefits from grazing the rare patches of Andropogon Gayanus, in order to safeguard the floodplains and streambeds. However, if the spatial extent of the Andropogon Gayanus, by some miracle, starts to increase, then it may become profitable to use the Andropogon Gayanus-dominated areas.

3.4.4. Succession and Retrogression Studies

Since nearly 10% of the project area is already denuded and another 10% is estimated to be degraded and on its way to denudation, much of the research activities emphasized the understanding of the causes, processes and impacts of rangeland degradation.

Both "degradation" and "denudation" are relative terms. Whether an area is degraded or not, and the degree to which it is degraded, depends ultimately on the objectives of the management strategy. Denudation, on the other hand, is easier to define since it can be based on a measurable reduction in the vegetation community. However, the exact point at which an area becomes denuded is usually unclear, and much argument can surround a decision as to whether the land is irreversibly denuded. Another related term is the much abused word "desertification." The popular press has inflated the definition much beyond its original meaning, ie., a geographical expansion of the desert (UN Conference on Desertification, Nairobi, 1977). In this report, denudation will refer to the process by which the soil loses its vegetation cover. Degradation will refer to the general stages before denudation sets in.

There are two major types of denudation currently prevalent in Africa north of the equator. The first is denudation of coarse sandy soils which may result in the formation of moving dunes. This type of denudation appears almost exclusively north of the 300 mm isohyet and is rare until one reaches the 150 mm isohyet (Penning de Vries, 1982: 360). The second type of denudation occurs on sandy loam to loamy soils anywhere north of the 900 mm isohyet. It covers a much larger geographical area than the first type of denudation, and is much more prevalent in the 300-600 mm isohyet zone.

There are many causes of denudation in the Sahel, and each factor may aggravate itself and other factors. One such factor is the inherent quality of the soil. Loamy soils are very sensitive to erosion precisely because of their heterogeneity. Thus, a reduction in soil cover can quickly expose these soils to both wind and water erosion. In addition,

they are more susceptible to compaction than clay or sandy soils. This compaction can be produced either by raindrop impact or by trampling. Again, a reduction in soil cover can increase these effects, leading to a compacted soil where most seeds cannot find conditions suitable to germination, and where water and most roots cannot penetrate. In the end, these denuded areas can become severely compacted (sometimes reaching a bulk density of 1.82).

There are four major reasons for the reduction in soil cover in the project zone, all of which to a greater or lesser degree are applicable elsewhere in the Sahel. One reason is drought, which has periodically afflicted the Sahel, and will probably continue to do so. Drought weakens and reduces the productivity of the plant community so that the "safety margin" between exploitation and overexploitation is reduced. Although drought by itself may not be a causal agent, it does nevertheless compound the effects of other factors.

A second reason is the reduction in tree cover. Live trees are cut for construction of fences, houses and barns. Cooking fires consume a very large amount of wood. However most of this fuelwood consists of dead fallen branches since they tend to burn easier. The tree cover not only protects the soil from high winds and raindrop impact, but it also provides shade for the herbaceous layer. Without this shade, most herbaceous species could not withstand the 2-3 week dry spells that occur frequently early in the rainy season.

Certain features of the cultivation system also play an important role in the reduction of soil cover. Most cultivated fields are located on the floodplain areas where slopes may be as high as 3%. In the rainy season there is a loss of topsoil primarily because plowing does not follow the contour of the land. In the dry season, after the livestock have grazed off all the crop residue, the soil remains exposed to the strong winds.

But by far the most important factors contributing to soil degradation in the floodplains are grazing and trampling by livestock. Because of the nature of the soil and grazing patterns, these effects are much more destructive in the rainy season than in the dry season.

In the dry season livestock will tend to graze off whatever remains on the soil around villages. The destructive role of sheep and goats is more important in the dry season than that of cattle since the former remain on the floodplains, not moving further than 3-5 km from the village, and tend to browse on any surviving bushes and trees. On the other hand, cattle in the dry season tend to move onto the ironstone plateau in order to graze on the short grasses, such as Schizachyrium nodulosum and to browse on the Boscia senegalensis that dominates the termite mounds.

However, in the rainy season, the destructive role of cattle becomes relatively more important. With the first rains the herbaceous vegetation starts to germinate earlier in the streambeds than elsewhere, and cattle will congregate on these areas. In this season the floodplain and riparian range types support a variety of palatable grasses and legumes. Thus the fragile slopes of the floodplains feeding the drainage ways are heavily trampled which gradually results in a compaction of the subsoil. It is only at the end of the rainy season, when the grasses enter their flowering stage, that livestock will move to the ironstone plateau. But by then, as far as the floodplains are concerned, it is already too late (see section 3.2.1.3.).

Aerial photographic interpretation of the Project Zone shows that in 1983 a total of 22,674 ha of land were already denuded. Fourteen percent of this is in the Gambia Basin, and the rest in the Senegal Basin (most of it concentrated close to the Senegal River, especially between Gourel Alassane and Bakel). A comparison of aerial photos from 1953 (only available for Gambia Basin) and 1983 show a very depressing picture of expanding degradation. Figure 3.5 provides an illustration of the expansion of denuded lands around some villages. Table 3.22. shows the hectares of denudation.

The data show that on the average there has been a yearly rate of increase in denuded land area of 5.65 ha per village per year in the Gambia Basin.

Section 3.6.1 will deal with the problem of revegetating the areas that are already denuded. This section will try to describe the changes that may occur in the vegetation community. One of these changes is due to increasing grazing pressure, which is referred to as "retrogression" of the community. The "succession" of the community refers to the changes in the opposite direction, ie., the successive changes from a highly used state, to a nonused state.

The only reliable way of studying the succession is to actually fence off an area. Two sites, each a hectare in size were fenced off in October 1984 using metal posts and tension sprung barbed wire. One site is in the Gambia Floodplain and the other in the Senegal floodplain. Both are located in areas that are well into the degradation cycle. The successional changes may be visible even after the first year especially in the herbaceous strata. It is recommended that a long-term effort be maintained in collaboration with LNERV/ISRA to monitor these sites.

In 1979/80 Dickie (1982) conducted an extensive survey of the woody species of the (equivalent of the) Gambia River Basin's ironstone and floodplain/streambed range types. As part of this survey he was able to correlate the changes in the vegetation community with the distance from permanent or temporary water-points. In that survey he concluded

FIGURE 3.5.

WESTERN PART OF GAMBIA BASIN AREA:
EXPANSION IN DENUDED LANDS, 1953-1983

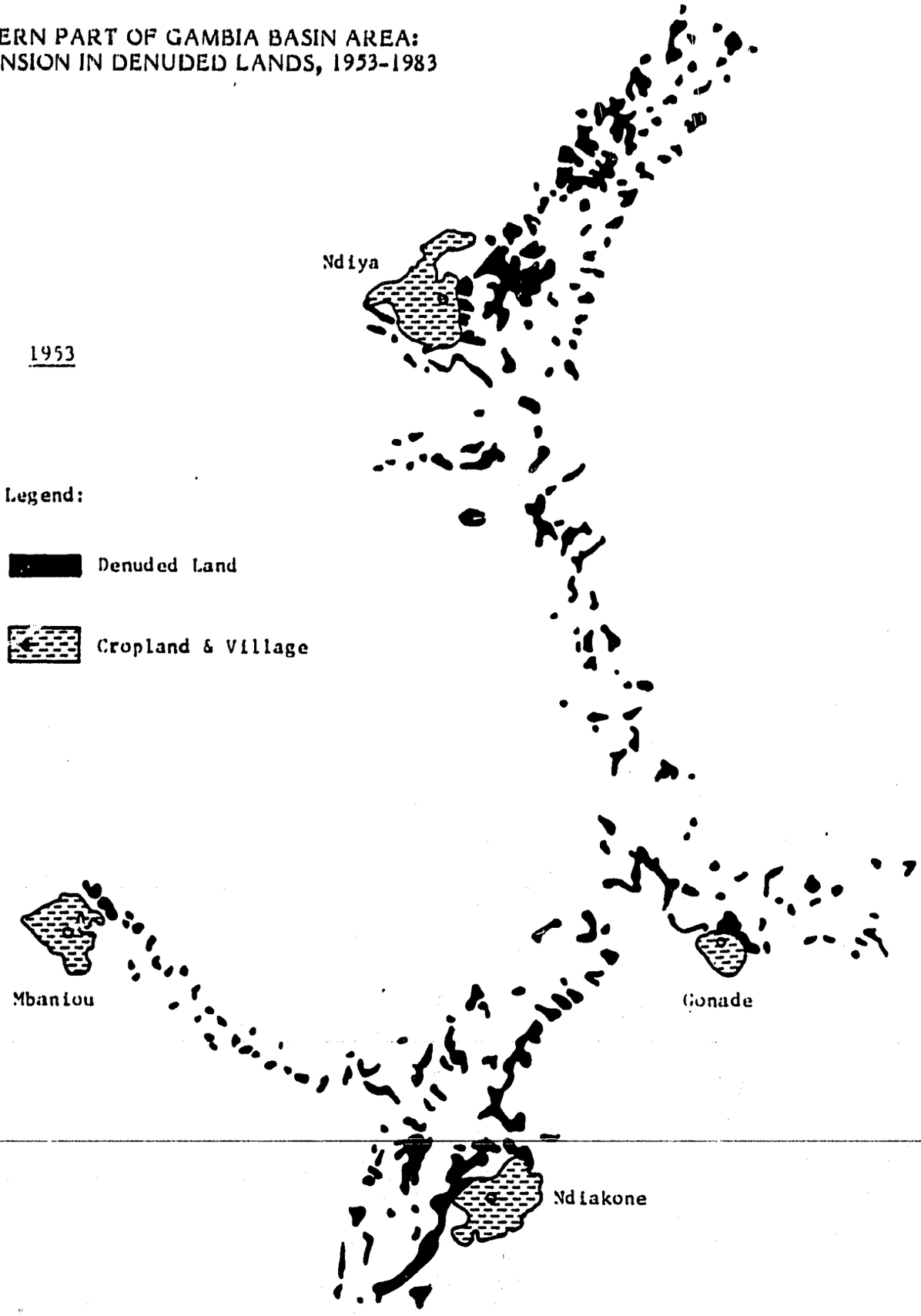
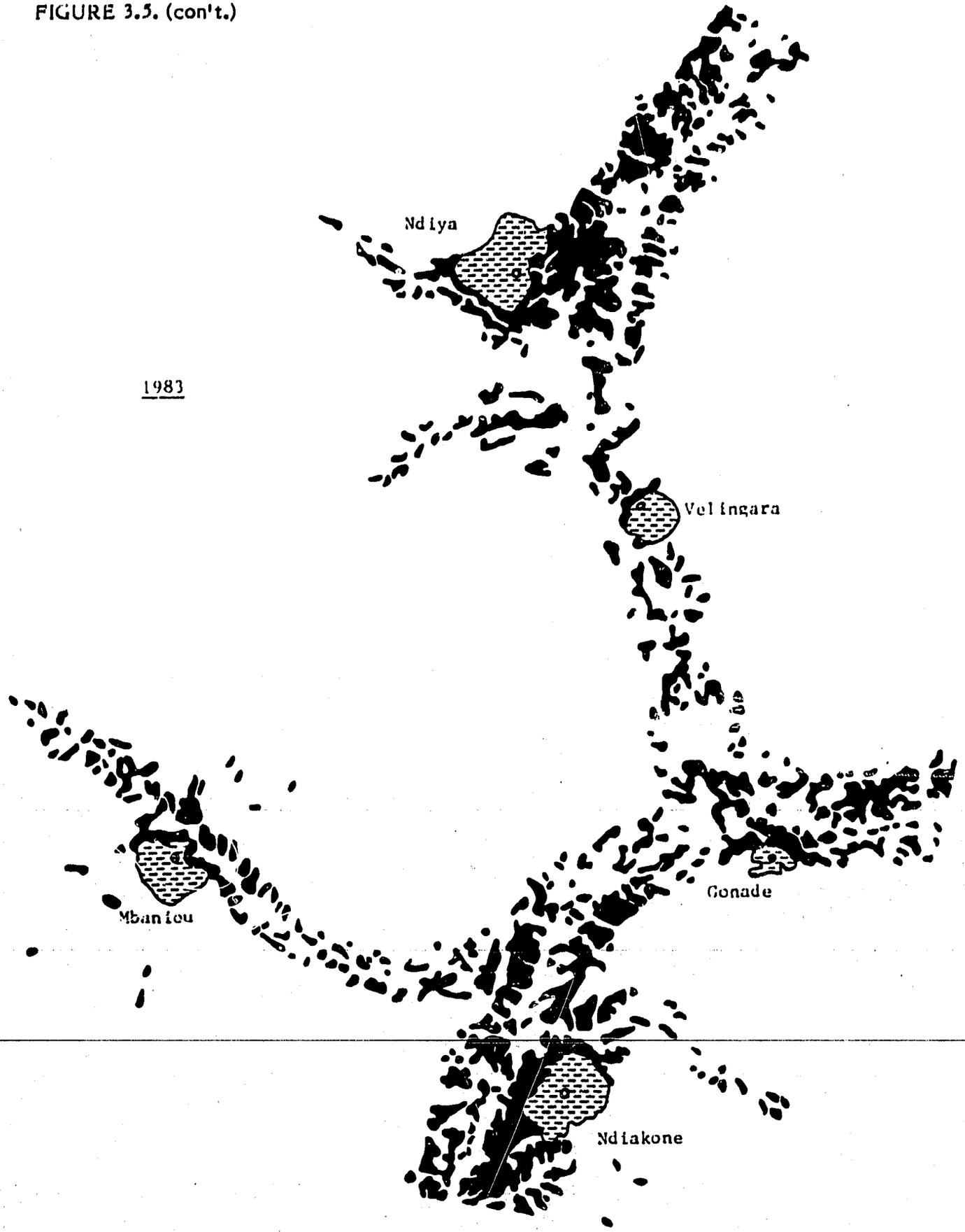


FIGURE 3.5. (con't.)



that there is a negative relationship between the distance to water and the dominance of shrubs. In other words, as the distance decreased, the dominance of shrubs increased.

TABLE 3.22.

DENUDED LAND AREA IN GAMBIA BASIN, 1953-1983
(ha)

Village(s)	1953	1983	Difference ha	Difference %	Average Increase ha per year
Toulekedi	62.9	317.8	254.9	405	8.5
Boulel and Thieké	114.5	374.2	259.7	227	8.66
Ndiya and Velingara	188.7	372.6	183.9	97	6.13
Mbaniou, Ndiakone and Gonadé	193.6	517.8	324.2	167	10.81
Diare Mbolo, Garalla, Diare Maboube and Medina Guiraye	316.2	1325.9	1009.7	319	33.66
Sowol	n/a	235.5	--	--	--
Total (without Sowol)	875.9	2908.3	2032.4	232	67.75

SOURCE: Survey data.

In 1984 we were able to conduct another survey on the retrogression of the plant community. This study was done on two range types: floodplain (Gambia) and foothill, with loamy and sandy loam soils respectively. The study consisted of choosing 4-5 sites in each range type. The five sites were located in an increasing distance from a village (permanent water-point). In order to verify that the sites indeed reflected increasing grazing pressure, data were collected on two other variables: (1) biweekly collection of livestock manure from a 100 m^2 permanent plot in each site and (2) placement of five cages (one meter square each) before the start of the rains. At the end of the rains the biomass in the cages, as well as outside the cages, were cut, dried, weighed, and compared.

The herbaceous data were measured every month by counting the number of individuals in 20 x 400 cm^2 quadrats, which were placed at regular intervals on a permanent line transect. The woody species were measured by counting the number of individuals larger than 0.5 cm in diameter, and recording their basal diameter, in 10 x 300 m^2 plots in each site. Other data collected include: (1) number of seeds per square meter in 3 different soil depths before the start of the rains; (2) number of seeds per

individual in each key species; (3) soil texture, bulk density, slope and infiltration rate; and (4) above ground biomass of key species. The full analysis of this data is the subject of the author's doctoral thesis. However, the salient results will be discussed here with an eye toward the development of a management strategy.

The results of the study to date show that there is indeed a retrogression in both the herbaceous and woody strata of the plant community. Table 3.23. resents a summary of some of the results. The "stages" refer to a gradual change from 1 equalling no degradation to 5 equalling partial to full denudation. The indicator plants are not necessarily the dominant species in their strata, but are plants that invade or are relatively more abundant in the particular stage. Three salient points can be derived from the results. On the one hand there is a decrease in total herbaceous biomass associated with increasing grazing pressure. Secondly, there is a general trend first toward bushes and hardy dicots, and then toward plants (whether herbaceous or woody) with deeper roots that can withstand the relative decrease in soil moisture availability. Thirdly, the exact sequence of plants depends very much on the soil type. For example, it can be seen that Aeschynomene Schimperi is an indicator of stage 5 in the foothills (sandy soils) but of stage 2 in the Senegal floodplain (loamy soils).

The list of indicator plants can be used in a flexible resource management strategy. They can become part of an "early warning system" that is used to assess the condition of the range by range technicians and herders. The number of animals allowed on any pasture would then be increased or decreased depending on the condition/stage of the pasture. This point is elaborated in the Range Management Plan.

3.4.5. Conclusions and Recommendations

The studies done on the range productivity to date show that the rangelands are composed of an annual nerbaceous community with a good mixture of grasses and native legumes. They also support an important woody stratum that has many palatable species. The range as a whole is primarily suited to a diversified industry of small and large ruminants.

However, the rainfall patterns result in a tremendous variability in the availability of the annual biomass. This variability is apparent not only in time (eg., between years), but also in space (from one spot to the next). The lack of control over these factors means that the management strategy has to remain flexible and acutely aware of small changes in the productivity of the land.

The forage is of a fairly high quality in the wet season, but this quality quickly fades as the dry season advances. The presence of nondecidious trees during the dry season is a

TABLE 3.23.

INDICATOR PLANTS[a] AND BIOMASS[b] OF RETROGRESSIVE STAGES IN THREE RANGE TYPES IN 1984

Stages	Gambia Floodplain			Senegal Floodplain			Foothill		
	Herb	Woody	Biomass	Herb	Woody	Biomass	Herb	Woody	Biomass
1	Bor stac	Com glut	1020	And pseu	Com mic	2257	Ari stip	Lan acid	?
2	Lou tog	Comm afr	1218	Aes schi	Aca sey	?	Dact aeg	Com glut	1012
3	Bor rad	Gui sen	1122	Hyb thes	Aca sen	1114	Ari mut	Gui sen	432
4	Zor glo	Bos sen	522	Spo coro	Bal aeg	?	Zor glo	Aca sen	410
5	Mic ind	Lan vel	218	Mic ind	Cal pro	80	Aes schi	Comm afr	312

SOURCE: Survey data.

NOTES: [a]All biomass reported as kg-DM/ha.

[b]For full name of indicator plants, see Table C1.

helpful boost to livestock diet. However, studies suggest that the livestock are faced with protein and some mineral deficiencies. Supplementation of the diet of livestock would probably result in impressive gains in milk, live-weight and work-energy of livestock.

Bush fires devastate almost 50% of the rangelands every dry season. Not only does this mean less forage in the dry season, but studies also suggest that yearly bush fires tend to result in an increase of less desirable bushes and a decrease of legumes. In terms of the ecology and the livestock industry this is not a desirable trend. However, fires at regular (3-5 year) intervals would probably be beneficial. But to implement these beneficial fires, much more control needs to be exerted over people and pastures.

Studies of the community productivity suggest that if certain range types (especially floodplain and streambeds) are not used during the wet season, then their overall herbaceous productivity and the theoretical stocking potential would increase. These results are incorporated in the Range Management Plan.

Studies also show that denuded land areas have been increasing at an average rate of 5.6 ha per year per village since 1953. The main causal agent is overgrazing especially during the wet season. Therefore the solutions must include, on the one hand, revegetation of areas already denuded, and on the other, prevention of further degradation.

In order to verify and complete the data on the range productivity, the following research activities are recommended:

- Continuation of yearly biomass studies on existing sites;
- Research on the productivity of the woody species;
- Continuation of research on the ecological impacts of bush fires;
- Continuation of the monitoring of succession and retrogression study sites;
- Grazing trials on the two important range types (both of the floodplains) or, if resources are limited, continuation of the clipping studies.

3.5. RANGE STOCKING CAPACITY AND POTENTIAL

The usual method of calculating stocking capacities is to divide the theoretical forage need of livestock by the amount of forage available which is measured through biomass studies (section 3.4.1.). However this method is not totally satisfactory because it only provides figures on the dry season capacity. In addition, this method assumes that livestock have access to all parts of the range, however remote they may be from a

source of water. Finally, this method does not take into account the many detailed variations in the rangeland's productivity, nor the contribution of trees and shrubs to the diet of livestock. Given these reservations then, the figures provided in Table 3.24. must be taken with much skepticism, and used only for providing a guideline to the general capacity of the rangeland.

3.5.1. Theoretical Calculations

Table 3.24. compares the actual stocking capacity in the dry season for a moderately good year (1983) and a bad year (1984). It also provides the potential stocking capacity. This theoretical potential is derived from the clipping studies done in 1983/1984, and assumes that the best treatment is followed. The data show that, at least for the range types that were studied, the potential dry season stocking capacity is much higher than the actual, even in a good year. The only exception is the ironstone plateau which appears to be overused in a good year's dry season, but underused in the wet season (see section 3.4.3.1).

Until such time as the recommendations from the clipping studies can be implemented, the rangelands will at best be used according to the actual stocking capacity figures. Therefore, the following calculations have used those figures. These calculations unfortunately ignore the important contribution of trees and shrubs to the diet of the livestock, since data was not available. Therefore, the stocking capacities have erred on the conservative side.

Assuming that in the dry season, 50% of the rangeland is burnt, and only 67% of the rangeland is accessible to livestock (because of the lack of water), and 10% of the land is denuded, the figures show that there could be 27,530 UBT grazing on the Gambia Basin range, for the entire dry season in a good year. However, in a bad year, there could only be 10,810 UBT for the dry season. The comparable figures for the Senegal Basin are 17,600 UBT in a good year and 11,110 UBT in a bad year.

Recent livestock censuses of the project zone show that there are approximately 9,500 UBT in the Gambia Basin, and possibly 10,000 UBT in the Senegal Basin in the dry seasons (these figures do not include the livestock of nomads nor the livestock of the project villages that are forced to go on transhumance). It appears that the project zone as a whole may still have some surplus capacity but only in a good year. In a drought year, the "safety margin" becomes too narrow.

By opening up nonused pastures through water development, and controlling bushfires down to a manageable 5%, the dry season stocking capacities could be increased to 30,600 UBT in the Gambia Basin and 31,500 in the Senegal Basin even in a drought year.

TABLE 3.24.

THEORETICAL STOCKING CAPACITIES AND POTENTIALS[a] FOR RANGELANDS IN PROJECT ZONE IN 1983/84

Range Type	Actual Stocking Capacity (ha/UBT/dry season)		Potential Stocking Capacity		
	Good Year (1983)	Bad Year (1984)	Wet Season ha/UBT/120 days	Dry Season ha/UBT/245 days	All Year Average
Ironstone	1.3	3.8	0.8	2.8	1.5
Floodplain (G)	2.3	5.3	0	0.8	1.1
Floodplain (S)	1.8	2.6	N.A.	N.A.	-
Degraded (G)	33.0	52.0	N.A.	N.A.	-
Degraded (S)	6.4	55.5	N.A.	N.A.	-
Hill	2.4	10.2	N.A.	N.A.	-
Foothill	1.5	5.8	0.6	2.3	1.2
Streambed (G)	1.4	2.2	0	0.2	0.3
Swamp	2.1	2.4	N.A.	N.A.	-

SOURCE: Survey data.

NOTE: [a]Assuming 9 kg DM forage consumption per UBT per day.

3.5.2. Conclusions and Recommendations

Theoretical calculations of the actual stocking capacities in the project area show that given the present conditions of lack of adequate water distribution, losses of up to 50% in yearly biomass due to bush fires and 10% of denuded land surfaces, the actual stocking rate (ie., number of animals actually on the range) is very close to the stocking capacity of a dry season in a bad (drought) year. This stocking capacity may be increased in good years. However, given that for the past ten years we have had more bad than good years, then the stocking rate should not be allowed to increase beyond its present limits. It is recommended that until the present resource constraints are resolved, the stocking rate be kept under a ceiling of 10,000 UBT/dry season in the Gambia Basin, and 11,000 UBT/dry season in the Senegal Basin (this applies to all livestock, not just cattle). If, however, bush fires could be controlled, denuded areas could be revegetated, water points could be developed in decentralized areas, and herders could be employed year-round (in order to follow the recommendations on range use) then the stocking capacity could probably increase by 300%.

3.6. RANGE IMPROVEMENTS

The range improvement program had two major objectives. The first was to find ways to revegetate denuded areas and to recommend degradation prevention methods. The second was to evaluate the effects of the drought on the rangeland, and to study the need for the introduction of new forage species.

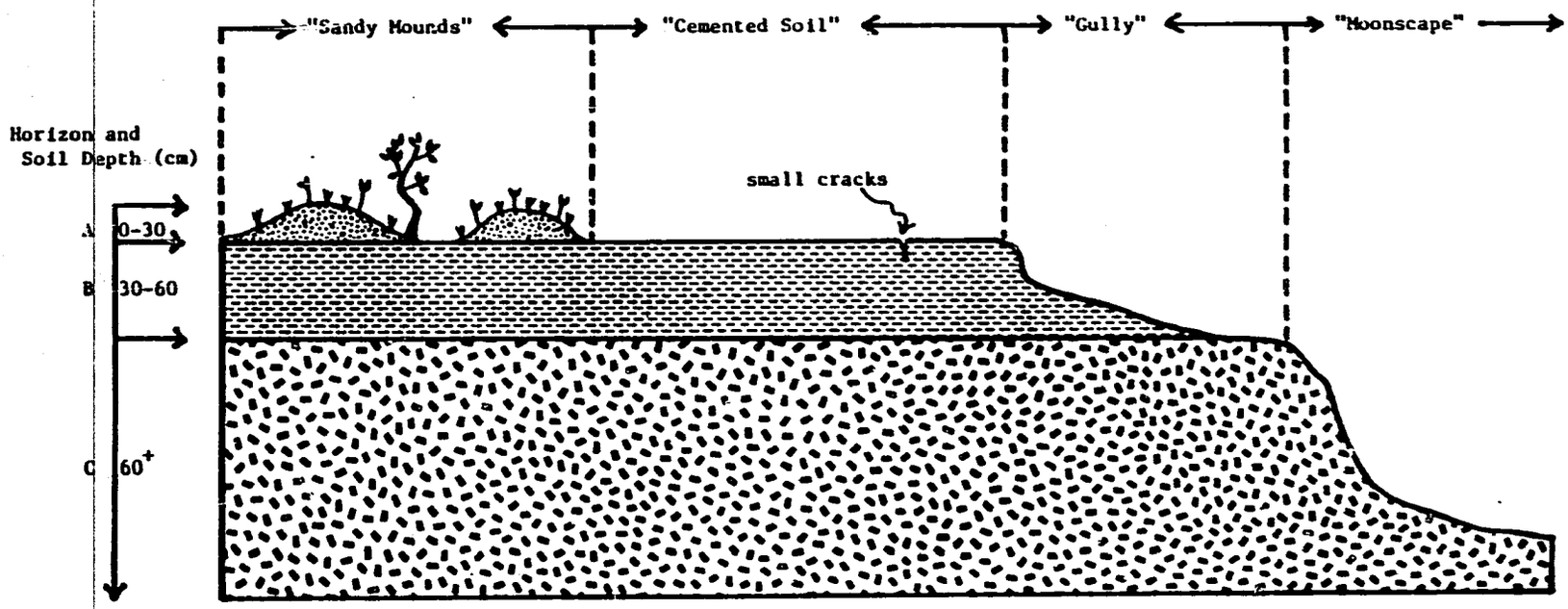
3.6.1. Revegetation of Denuded Areas

Section 3.4.4. gave a detailed explanation on the causes and processes of degradation and denudation. It is clear that a two-pronged approach to the solution is needed. On the one hand, livestock management practices must be modified in order to prevent further degradation. This is discussed in the Range Management Plan. On the other hand, the existing denuded areas must be revegetated in order to prevent further erosion of the soil.

There are four major types of denuded areas in the project zone, most of which occur in the floodplains of both the Gambia and Senegal Basins. Figure 3.6 provides an illustration of these main denuded soils.

The first type, labelled "sandy mound," refers to the initial process of soil erosion. Trampling tends to loosen the top few centimeters of soil, while compacting what is underneath. Rain and wind will erode the finer soil particles on the surface, leaving

FIGURE 3.6. Typical Cross-section of Denuded Areas, showing Four Types of Denudation



behind the sandy particles, which in turn, will cling to any remaining grasses or shrubs. Therefore the area has the appearance of islands of sandy mounds.

The second type of denudation is labelled "cemented pavement." Here, all the grasses on the sandy mounds have been grazed and the sands eroded, leaving an almost smooth, very compacted, soil surface. Lichens will tend to take over and cover the surface. Because of the compaction, water infiltrates only 5-10 cm into the soil, therefore trees and shrubs cannot survive. Only a few, short, hardy grasses can survive, along with some perennial bulbous plants (Liliaceae family). Permanent metal markers had been placed on one cemented site in April 1983. These were monitored the following year, and it was found that on the average the top soil had eroded by 1.2 cm in depth -- this is equivalent to 193 t/ha/year, which according to the FAO, is classified as a high rate of erosion (FAO, 1979). Where lichens have covered the surface, there is less erosion of the soil, but lichens also reduce even further the infiltration rate of water because they tend to absorb three times their volume in water, and thus create an impermeable layer over the soil.

Wherever there are small cracks in the soil, water erosion may take hold and create eroded gullies. The beginning stages of this process result in 1-10 cm drop-offs with the soil being deposited on the downward side of the gully. This is the third type of denuded area and is labelled "gully." The fourth type, labelled "moonscape," is an advanced stage of the gully formation. Here the erosion exposes the subsoil (C-horizon) in the gully. The remaining soil is alkaline and cannot support any vegetation. No attempts were made to revegetate these moonscapes. It was felt that these areas were too far advanced in the erosion process and nothing, short of transporting virgin soil, would rejuvenate them.

In the 1983/84 period, five techniques for revegetating denuded areas were tested in the Gambia Basin area. The main objective of the experimentation was to find a technique that would be feasible on a large scale, and would use local resources. The experiments were done on four sites, each site being 1/2 ha, although not all sites received the same replications.

3.6.1.1. Fencing

Fencing was done to enclose the study site, using local techniques. This consisted of wooden posts spaced 50 cm apart, with three rows of cross-branches tying the posts together. Spiny brush were then tied to the fence. The result was a pretty sturdy fence that even a goat would have a hard time getting through. An attempt was made to use only dead branches, but there were relatively few that were still in good shape. Therefore, the people had to cut live branches. This, of course, contradicts the whole

purpose of the attempts at revegetation. In general it took 20 men one day (8 hours) to build 100 m of fence (this includes collecting and transporting the wood).

In general it was found that most of the fence posts had to be replaced at least once every year (more often if they were knocked down by animals) because of termites and wind damage. The spiny brushes had to be replaced frequently, especially in the dry season because of the wind.

It was found that fencing, by itself, only had a positive effect on the sandy mound type of denuded areas. In these areas the process of denudation is only just beginning, and a simple exclosure (ie., elimination of grazing) does result in an increase in the vegetation cover. However, fencing is not enough on the other three types of denudation.

3.6.1.2. Dead-Wood Dikes

This technique involved the placing of small wooden dikes on the soil that were perpendicular to the slope (following the contour lines). As much as possible dead tree trunks and branches of at least 10 cm in diameter were used. If the slope was steep, then small retaining stakes (also wooden) were drilled just downslope of the dikes. Wherever the tree trunks did not touch the soil, the gaps were filled in with smaller pieces of wood. The result, in the ideal cases, was a continuous diking of the soil.

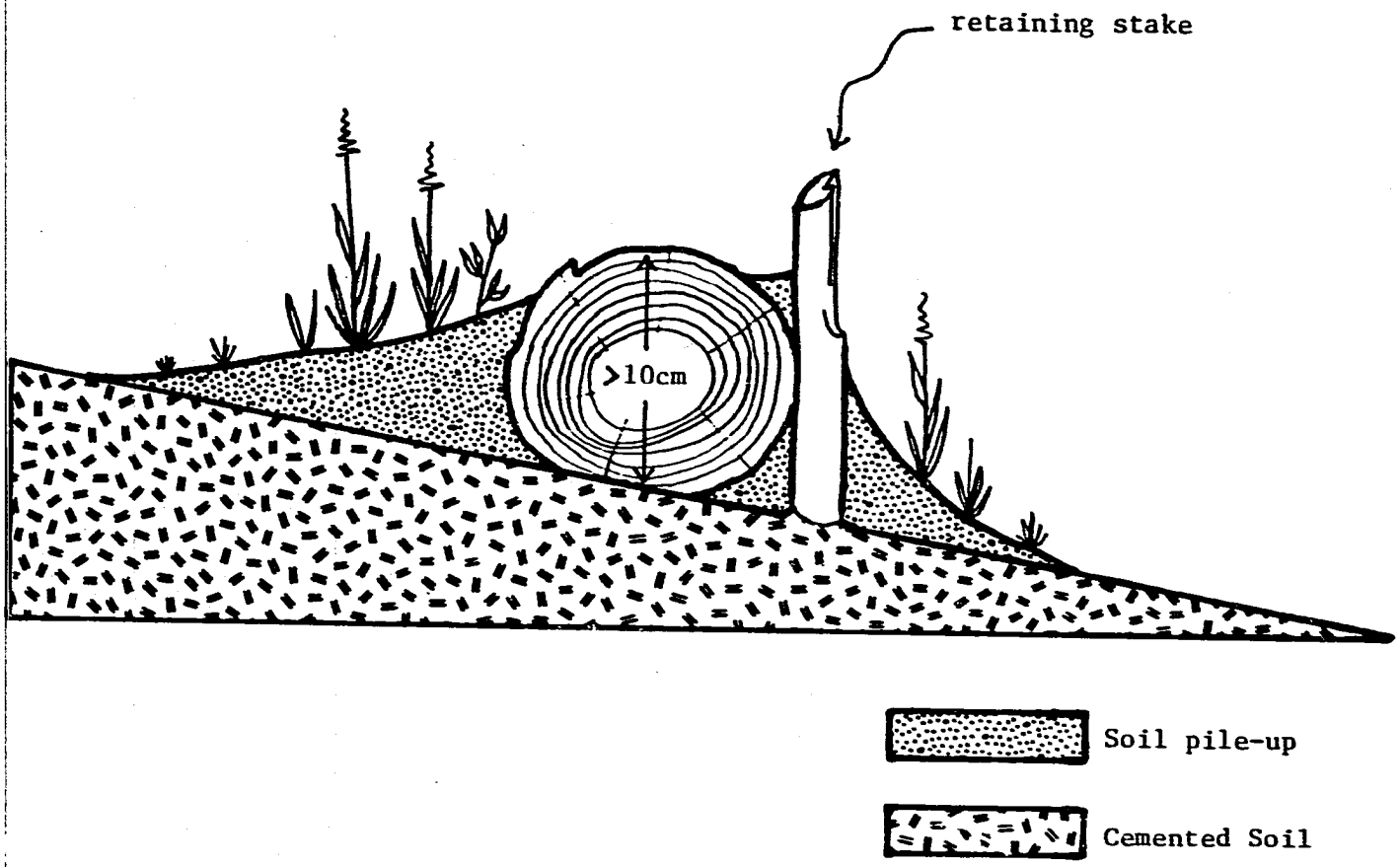
The principle behind this technique has been tried elsewhere in Mali (Penning de Vries, 1982: 440) and is illustrated in Figure 3.7. The dead-wood dikes act as retainers of both the soil as well as seeds, so that in the rainy season the plants (mostly grasses in the first year of succession) can take hold if they are not grazed. In addition, their roots can become quite vigorous and help to loosen up the compacted subsoil. In subsequent years, the pileup of soil expands, more herbaceous plants establish themselves, and eventually the soil's infiltration rate increases enough to allow the growth of trees and shrubs.

In general, it took 20 men one working day to place dikes that were 4 m apart on 1/6 ha of land (including transportation of the wood to the site). The dikes were subject to some attack by termites, but the rate of replacement of the wood was not very high.

The results of the experiment were encouraging. The technique was more effective on the cemented and the gully types of denuded areas. The dikes were effective in preventing the advance of the gully, and in revegetating the areas downslope of the gully. In the first year of the experiments, the vegetation cover in the gullies doubled (from 1.5% to 3.8%), and the number of different herbaceous species increased from 2 to 6.

On the cemented soils, the soil pileup increased from 0 to 20% percent of the cover in the first year, but did not significantly increase in the second year. The vegetation

FIGURE 3.7. Cross-sectional Diagram of Dead-Wood Dike Technique



cover increased from 0 to 1% in the first year (and did not increase significantly in the second year).

The lack of cumulative effects of the dead-wood dike into the second year may be due to the fact that the dikes were spaced too far apart (4 m). A 2-meter spacing between the dikes would probably be more effective.

3.6.1.3. Tree planting

During the retrogression studies (section 3.4.4.) it was noted that Acacia Senegal appears to outlast other trees on degraded soils. Therefore seedlings were raised in the project's nursery, and along with seedlings of Parkinsonia aculeata, were planted on the sites. Individual pits of 50 cm depth and 50 cm diameter were dug 5 meters apart. The seedlings were planted along with two handfuls of pulverized sheep manure, and they were watered once by hand. It took 20 men four hours to dig and plant 500 seedlings (this does not include raising or transporting the seedlings).

In general it was found that the Acacia Senegal performed better than the other tree. However, the date of planting was too late in the rainy season, and the majority of trees died during the dry season. In addition, the author does not expect the trees to survive in the long run because of the lack of a herbaceous cover that would reduce compaction of the soil and allow infiltration of water to the roots of the older trees.

3.6.1.4. Ripping with draft animals

This technique was used only on the cemented soils. A pair of oxen were hitched to the local disk, and the soil was ripped up to a depth of 10 cm. The work was done immediately after a rain but even so, the soil was very hard, and the blade could not go any deeper. It took two men and two oxen three hours to rip lines that were spaced 4 m apart and followed the contour, on 1/6 ha of land.

The results were remarkable. Wherever the blade had loosened the soil there were grasses and even some dicots. However the effect was not cumulative; in the second year the vegetation cover was slightly less than the first year, unless the soil was ripped again. In addition, it appeared that some of the loosened soil had been eroded off. Finally, there was a problem of labor shortage: with the first rains the people are busy plowing and sowing in their fields, and there is no time to plow denuded areas.

3.6.1.5. Ripping with bulldozer

Another cemented site was chosen in May 1984, and the soil was ripped using three bulldozer-teeth that were placed one meter apart. The ripping was achieved at a depth of up to 50 cm. It took one bulldozer one hour to rip a 1/3 ha area. The ripped lines were

seeded with Cenchrus ciliaris var. Gayndah, Cenchrus ciliaris var. K.A., Aeschynomene falcata, and Macroptilium atropurpureum, at a rate of 3 kg/ha.

The rate of vegetation growth in the first year was not impressive. Of the seeded plants, all germinated except for Cenchrus ciliaris var. Gayndah. Other local species also invaded the area, such as Panicum laetum and Zornia glochidiata. However, the overall density of herbaceous plants was very low (on the average 10 plants per ripped meter). It appears that, at least in the first year, the ripping turns over large blocks of compacted soil. As a result, most seeds get buried too deep with the ensuing rains, and only some find suitable conditions for germination. It is possible that the second year may see a positive cumulative effect.

The Service Eaux et Forets program in planting gum arabic plantations shows more positive results. They used a tractor-drawn single ripper on less compacted soils to draw lines on which the seedlings could be planting. One of their unexpected results was a lush growth of herbaceous plants on the rip lines.

3.6.1.6. Conclusions

Of the four techniques that worked the soil, each technique has its advantages and its disadvantages. The dead-wood technique is effective and cheap but it will take many years to have a full impact. The ripping by local disk is also effective, but the problem of timing and labor shortage will be difficult to surmount. Planting seedlings all by themselves is probably not worth the while in the long run. Tractor or bulldozer ripping is probably the fastest way to revegetate the cemented areas, but the costs are high, and the means are available only through the Government.

The best solution for revegetating the denuded areas appears to be a mixture of all the techniques tested. The most effective way would be to rip the soil (rip-lines spaced one meter apart), plant Acacia Senegal in the lines every 5 meters, and place dead-wood retaining dikes every 5 meters downslope of the trees (the dikes would not be necessary on perfectly flat land). This combination of techniques would allow a rejuvenation of the soil, of the herbaceous layer and of the woody layer, all at the same time. In addition, the extraction of gum arabic from the trees would be an added revenue for the villages.

The diking could be done by the people's own resources. A properly managed village nursery program could supply the Acacia Senegal seedlings. However the ripping would most probably have to be done by the government services or the project. Not only is there a problem of labor shortage during the ripping time, but also at the rate in which the soils were ripped by the draft oxen, it would take each village on the average 3 years to rip all the denuded areas around the village (assuming 8 hours of work per day, and two

draft teams per village). In addition, ox-ripping is not very deep and has to be done repeatedly at least for the first 2-3 years. The extent of the denudation is simply too vast to rely only on the people's resources. The project (or the Government) must contribute to the effort.

Since most of the experiments were carried out with the participation of the people, it was possible to assess their reaction. Most people are aware of the overall problem of expanding degradation. However, they either do not make the link between that and overgrazing, or if they do, they are not alarmed because they see so much more nondegraded land available. The situation does not appear to be a crisis for them, even though it may appear so to the technician. In the first year of the experiments the people were willing to participate as long as the project was willing to push them. At the end of the first year's experiment, World Food Program donations (sorghum, oil, etc.) were given according to the level of participation of the villages. In the second year of the experiment, some villages refused to continue the work unless they were promised more donations. It is clear that much more extension and education is needed in order to convince the people of the future implications of the degradation.

3.6.2. Introduction of New Forage Species

Since the 1968-1972 drought in the Sahel, profound changes in the species composition of rangelands has been observed by various researchers. These changes have been sustained in the 1975-1984 period by frequent smaller droughts. Two years are not enough for assessing the exact impact of these droughts in the project zone, nevertheless discussions with various researchers in Dakar and Bamako, studies of project reports and discussions with local people, have provided two major observations. On the one hand, the northern limit of *Bombax costatum*, a tall tree of the Sudanian Region, has progressively moved south. On the other hand there has been a marked reduction in the density and geographical extent of perennial grasses and forbs. At present there are only two perennial grasses in the project zone: *Andropogon gayanus* whose occurrence is now restricted to streambeds and waterlogged depressions, and *Aristida longiflora* which occurs only rarely on the foothills. Among the perennial forbs there are five species of the Liliaceae family, two of the Amaryllaceae family (all fairly well distributed) and one very rare species of the Leguminoseae family.

The purpose of the forage trials program was to test the adaptability of exotic, drought-tolerant perennial grasses and legumes. The eventual aim would be to try and replace the local perennial herbs that had been decimated by the drought. A denser

population of perennial herbs in the rangelands would provide green feed later into the dry season, protect the soil from erosion, and provide regrowth after a fire.

At first the idea of increasing the existing, local population of Andropogon Gayanus was discussed. But the experience of the PDESO Project in Tambacounda discouraged this idea. The PDESO had tried to propogate the Andropogon Gayanus by tillers (it is normally very difficult to propogate it by seed) but had found that the success rate was very low, and it took too much manpower (Diaw; personal communication). For our project area, where the average rainfall is 100 mm lower than in the PDESO area, the success rate would probably have been even less.

In 1983 and 1984 a total of 89 different forage species and varieties were planted in the Mbaniou Zone. The performance of all these species under rainfed conditions was evaluated in both years. Most of the species were planted in a 30 m x 30 m fenced site. The trees were first grown to seedling in a nursery, and then transplanted to the site. The shrubs and herbaceous species were all seeded by hand in a plowed and prepared bed. In 1983, the entire site was weeded twice. In 1984 only the seeded areas were weeded, but the rest of the site was not, so as to reduce soil erosion. The trials site had previously been cultivated with millet and sorghum. Appendix A. provides a description of the soils in the site which is characteristic of the Gambia floodplain range type. Of the remaining species that were tested, some species were planted on the degradation-control experimental sites, and others were broadcast onto existing pastures. Appendix D. provides detailed results on all forage trials.

Of the trees and shrubs that were tested, Acacia Senegal and Parkinsonia aculeata seem able to withstand the harsh conditions on the degraded areas. As discussed in section 3.6.1, these two species should be incorporated into a program for the revegetation of denuded areas. Leucaena leucocephala and Cajanus cajan are also adapted to local conditions but, would perform much better if they were irrigated from time to time. In addition they can only be planted on good loamy soils. It is recommended that these two species be planted in and around village so that their double values of forage and edible beans could be exploited easily. It is also recommended that the project rejuvenate the nursery program. This can be done either in a centralized fashion (nurseries in each zone's base), or decentralized (village-based nurseries). The latter would probably be more effective.

Two of the perennial grasses, Cenchrus ciliaris (varieties Gayndah and Nunbank) and Panicum antidotale appear to be able to survive given the rainfall conditions in the area. The Cenchrus spp. were very impressive all year round. During the second rainy season, C.C. variety Gayndah gave a total of 12.8 tons/ha of forage with three cuttings, and C.C.

be studied by the project. It is recommended that a village seed multiplication program be introduced, and the principles of fallow/crop rotation be extended to the farmers.

3.7. CONCLUSIONS AND RECOMMENDATIONS

There are various techniques for restoring denuded lands. Each of the five techniques tested has certain technical and economic advantages which make them appropriate for different soils and vegetation characteristics. However, the extent of the denudation is already so vast, that the people cannot be expected to revegetate it all by themselves, no matter what technique they use. The project must take on a more active role in motivating and assisting the people in this task.

The recent droughts have taken their toll on the rangelands. A few exotic drought tolerant perennial grasses and legumes appear to be adaptable to the project zone. More work needs to be done on finding an easy, appropriate way of disseminating these plants into the pastures. Other herbs and trees appear to be adaptable to the regeneration of degraded areas.

A few exotic plants were found to be adapted to conditions around the villages. These include forage trees that could be planted inside the village compounds, new bean crops that could be planted in association with the local sorghum or millet, and some legume plants that could be planted as a fertility-raising fallow/crop. It is recommended that the project encourage village-based nurseries and seed multiplication plots to supply the village's seed and seedling needs.

4. EVALUATION OF PROJECT ACTIVITIES

This chapter provides an evaluation of seven different project activities primarily from the range management point of view. Wherever appropriate, an attempt is made to evaluate these activities from a larger perspective.

4.1. WATER CATCHMENT PONDS

The role of the water catchment ponds in the use of rangelands has been discussed in section 3.2.1.2. The hydrological performance of the ponds has been evaluated in the Soils/Water Engineering Report. A synthesis of these two reports provides the following observations on an overall water development strategy in the Gambia Basin.

The main objectives of water-point development in the project zone are three-fold. The first objective is to provide water in the distant rangelands in order to make these pastures accessible to livestock. The second is to provide year-round water in these pastures so that the animals would not have to congregate around the village wells. The third objective is to ensure that there is some form of control over the number of animals that can use the water-point.

The water development program implemented thus far has consisted of 20 ponds and the repair of a few existing wells. This program has only partially achieved the first objective. The distant pastures are being used because of the existence of the ponds, but they are not being used all year. By not achieving the second objective, the ponds have only partially fulfilled the first.

On the other hand, the ponds have achieved the third objective of controlling livestock numbers, because they provide a finite amount of water. Unlike bore-wells and most of the local wells, only a finite number of animals can drink from the ponds before they run dry. This has meant that the water-points created by the project have not become a magnet for vast numbers of herds from outside the project zone.

The Soils/Water Engineering Report shows that the main reason for the failure of the ponds in giving an year-round supply of water, is due to the very high infiltration rate from these ponds (up to 90% of the total volume). This is because the project zone primarily has coarse sandy loam soils which have very high infiltration rates.

There are only two areas, in all of the Gambia Basin side, that have finer, clayey soils: Koli Mare and Dudi Mare, both existing natural ponds. Koli Mare was deepened in April 1984 from a half meter to a 5-meter depth. The performance of the pond improved very much at least until mid-October, when the range manager left the country. Given its

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performance during the dry spells of the rainy season, it is expected that this new Koli Mare will have water at least two months beyond its original lifetime. The advantage of deepening the natural ponds is that they already have a good circle of trees around them that reduce the evaporation rate. The other natural pond, Dudi Mare, is very large (1 kilometer long by 200 meter wide). In its natural state, this pond lasts until February in a good year. It is recommended that at least two basins of 4000 m^3 capacity be dug in different parts of this pond. It is expected that the life of this pond could also be extended by at least two months.

In the Gambia Basin area, there are no more appropriate sites for building good catchment ponds. However, the problem of reducing infiltration on the existing ponds should be considered. There are various techniques that can be used: plastic or metal sheeting, asphalt or cement, salt or bentonite, etc. All of the techniques would increase the cost of the ponds. Some of them may not be available locally, or may require high maintenance costs and expertise. However, if the infiltration rate could be reduced even from 90% to 55%, then there would be enough water in the ponds to feed the existing number of livestock for the entire dry season (even including a 15% evaporation loss which is overly conservative). If the infiltration rate was further reduced to 30% (which is the average long-term effectiveness of most pond lining methods), then each pond could water as much as 500 UBT for the entire year. In other words, the 20 existing ponds could adequately water the 10,000 UBT potential capacity estimated for the range for all of the dry season.

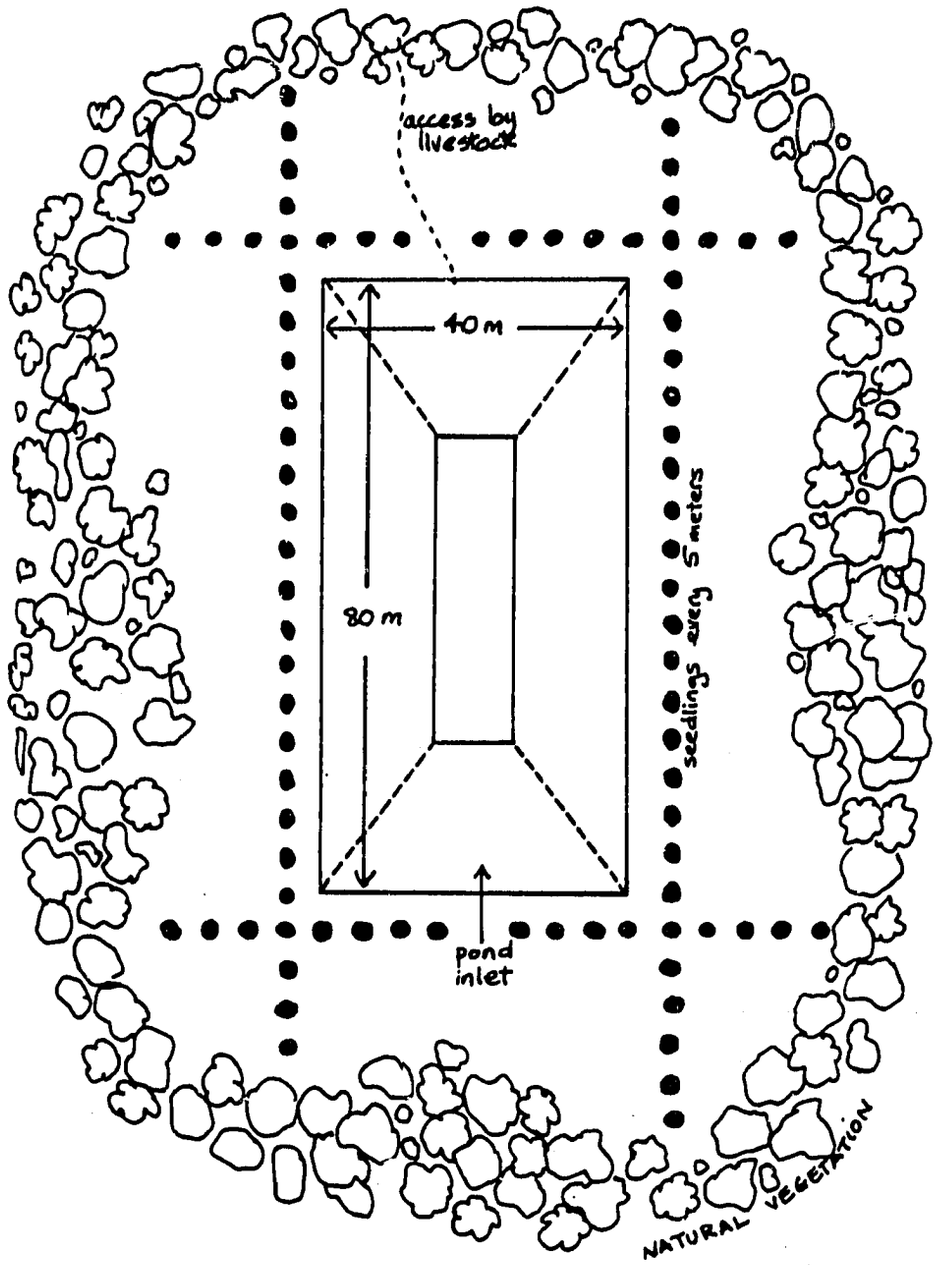
It is also worthwhile to consider the planting of trees (windbreaks) around ponds in order to reduce the evaporation rate. Up to now, the project has been using heavy machinery to clean out the ponds' sediment. Therefore it was not possible to plant trees around the ponds. However, this should be done in the future. The sediment from ponds should be cleaned every 2-3 years using a tractor or draft-drawn scoop. This would not damage the trees.

The rate of natural revegetation around the pond where the bulldozers have disturbed appears to be very high if the plants are protected from grazing. Since it would be difficult to control the livestock, it is recommended that certain nonpalatable, fast-growing trees (such as Eucalyptus spp. or Neem) be raised in a nursery and transplanted around the ponds. In their first year, the seedlings would have to be protected from trampling by animals by using thorny branches. Figure 4.1 provides a windbreak design for a typical pond.

As far as the Gambia Basin is now concerned, the water development strategy should consider three different alternatives:

FIGURE 4.1.

DIAGRAM OF A TYPICAL WINDBREAK DESIGN
FOR WATER CATCHMENT PONDS



Design Criteria:

1. Every meter of tree-height will cover 6 meters of pond; therefore, 80m pond length needs a 12m-tall tree (such as Eucalyptus spp., and 40m needs an 8m tree (e.g., Neem).

2. Because of wind dynamics around a tree, every meter of tree-height requires a 12m-long windbreak;

3. In most cases, the windbreaks will have to extend into the natural vegetation cover.

- no further investment;
- improvement of ponds by reducing infiltration and evaporation, and biannual maintenance;
- abandoning ponds and investing in wells.

The first alternative is favored by those who think that the problems are unsolvable and further investment would be a waste of resources. The range manager feels that the project area and most of the Boundou is a very important potential resource for the country's livestock industry. With some additional investment a viable resource program would most probably be developed. In addition, the problem of expanding degradation, with its roots in the constraints facing the livestock sector, threatens to affect the national ecology, and further investment into a range and water development program is indispensible in solving the degradation.

Table 4.1. provides a summary of the advantages and disadvantages for the remaining two alternatives.

The water in the natural and artificial ponds was tested for bacterial content by the Institut Pasteur in Dakar. They concluded that there was no difference in the bacterial count even in the first year of the pond's life. It would be interesting to test the difference in the parasitological content of the ponds.

The aquifer in the Gambia Basin is a nonrechargeable but continuous aquifer. Wells can probably be dug almost everywhere and touch water. However, they have to be deep (40-100 m) and they tap a nonrenewable resource. In addition, the experience of the PDESO Project to the South has been negative in the sense that their outlying wells are not being used by local herds (because there are no herders accompanying them to draw water) but rather have attracted nomadic herds or even entire villages who resettle around the wells. However, on the positive side, these wells can be dug through local resources. There are itinerant well-diggers who can use dynamite and cement for the wells when necessary.

The conclusion drawn from these observations for the Gambia Basin water development strategy, favors investment into solving the infiltration problem of existing ponds. It is felt that the marginal rate of return of investment into the ponds would be higher than that invested in wells. In addition, the ponds would assure a greater degree of control over the number of animals, and therefore would not aggravate the problem of overgrazing.

Up to now the ponds have been seen as an experimental exercise by the project. No thought had been given to the ownership of the ponds: who was responsible and who could

TABLE 4.1.

ADVANTAGES AND DISADVANTAGES OF INVESTING IN IMPROVEMENT OF WATER CATCHMENT PONDS VERSUS CONSTRUCTING NEW WELLS IN THE GAMBIA BASIN AREA

	Ponds	Wells
Advantages	1. Finite water source, therefore easy control over livestock numbers. 2. No human labor required to give water to livestock. 3. Uses surface water and saves on the nonrechargeable (fossil) aquifer.	1. Has no evaporation or infiltration problems. 2. Can be done by local means.
Disadvantages	1. Requires maintenance of technique used to reduce infiltration. 2. Has as much disease-bearing parasites and bacteria as natural ponds	1. Uses a nonrechargeable quifer. 2. Requires labor (or mechanical investment) to pull water. 3. May attract more animals into the Area.

SOURCE: Survey data.

use the ponds? Even though the ponds have now been assigned to respective pastoral units (see section 4.7), the original mistake was in not getting the people involved in the construction of the ponds (whether through capital or labor investment). However, it is not too late to involve them in the improvement and maintenance of the ponds.

It is recommended that a water development strategy for the Gambia Basin be initiated that would do research on improving the ponds, would test a few techniques for reducing infiltration, would design and implement windbreaks, and would organize a "Water Development Committee" in each pastoral unit with the primary function of improving and maintaining the ponds.

In terms of the management of range resources, the ponds are very appropriate to the wider context of the Sudano-Sahelian region. However, they are replicable only in areas with suitable soil and geographical conditions (such as the Niger Delta in Mali, or the Sud of Sudan). The cost of the ponds is prohibitive if the same designs are maintained. However, given suitable soil conditions, and a reduction in infiltration, the ponds could be made much smaller and probably cheaper.

The water development problems in the Senegal Basin area are much more complex. Ponds cannot be built there because the soils are coarser and the major streambeds are ravines with very steep slopes. Like the Gambia Basin, this area also has a few natural ponds that could be deepened. On the other hand, the groundwater aquifer is discontinuous and nestled in the chaotic folds of the schist and quartz bedrock, so that it would take a true diviner to strike water. Therefore wells, too, cannot be the main solution. It seems more appropriate, on the whole, to study the effectiveness of other water-harvesting techniques (such as metal runoff-aprons and tanks). The development strategy for the Senegal Basin is far from clear. Much more research and experimentation is needed to develop the strategy. It is recommended that the project hire a full-time hydrologist to test the appropriateness of other water-harvesting techniques in the Senegal Basin area.

4.2. FIREBREAKS

The original plans of the project for fire control were based on a system of firebreaks with watch towers in strategic locations that would house permanent observers. These observers would notify the antifire brigades in the villages who would then fight the fire with water-carrying unimogs and hatchets. It eventually became clear to many people that this program was too complex. The idea of unimogs, hatchets and permanent observers was abandoned fairly early in the projects' life (especially after noticing that none of the people were willing to even climb the watch towers!).

Since then, approximately 185 km of 7 meter-wide firebreaks have been constructed and maintained every year by the project's heavy equipment. The rate of regrowth of the vegetation is very high, and in almost all cases the firebreaks have to be cleaned every year. Most of the fires start in the month of October. Therefore the firebreaks have to be cleaned in the month of September (they cannot be cleaned earlier since the herbs will grow back). It was also found that the firebreaks that are perpendicular to the direction of the wind are not very effective in stopping the fires (the winds typically come from the either the east or the west). A strong wind can easily send embers flying across the perpendicular lanes. To be truly effective, the project would probably have to build another 150 km of east-west firebreaks in the Gambia Basin alone.

In various meetings with the project population, the question of cleaning these firebreaks has been brought up. The people had wanted the heavy machinery to continue building new firebreaks since they saw the firebreaks as being beneficial. They had suggested that at least some of the lanes could easily be kept clean since they were also

used as roads. However, this applies at the most to only one-fourth of the total lanes. The people did not know how they could clean the rest of the lanes with their own resources. Some thought can be given to designing draft-drawn scoops or scrapers that could be dragged on the soil. But even if these scrapers were totally effective, it would probably require about 20 teams to clean all the firebreaks in the one month of September every year. The month of September is also a heavy weeding period and not much time can be taken off from the farms. Therefore the problem of cleaning the firebreaks is not simple, and would require a lot of cooperation and planning among villages (or pastoral units).

Another aspect that requires a lot of management is the organization of antifire brigades. Traditionally, each village will send out its people to put out a fire that threatens the village or its fields. The people cut branches off evergreen trees and use these to beat down the fire. The work is hard, and the best result is that the fire is diverted from the village even though the fire itself continues to burn elsewhere. The major constraint to establishing antifire brigades for the bush has not been the lack of motivation, but the fact that the head of the fire can be miles away from the village. The people cannot be expected to reach that area in time to stop a major portion of the range burning. Therefore they sensibly concentrate on defending what they know is within limits of their resources.

Unfortunately the problem of controlling bush fires is more complex than anyone ever imagined. Firebreaks and fire brigades do not produce the desired impact. The policy of the Ministry of Protection of Natural Resources, implemented by the local Water and Forestry Service in Bakel, is destructive in the long run since it imposes a paramilitary solution on a social problem. We are still far from finding a viable, short-term solution. However, the project's extension efforts, and the fire control topics in the syllabus of the Functional Literacy Program may help to create a new generation of fire-conscious people in the long run.

It is recommended that the project attempt to find and introduce alternative methods of honey gathering and hunting that would not require the use of fire (see section 3.4.1.2.). If the incidence of fire due to these two causes were reduced, the extent of fire damage to the rangelands would probably decrease sharply. The solution to the problem of bush fires must concentrate on changing the causes as well as curing the symptoms.

4.3. COMMERCIALIZATION OF LIVESTOCK

Until 1983, the project's commercialization program had existed essentially on paper. Since then the program has been revitalized. A few studies have been conducted on the Bakel market and the National Trading System (Diaw; 1983), and the socioeconomic research team have done an extensive village-level study (see the Socioeconomic Study Report).

In the past year, the commercialization program has concentrated its efforts on buying livestock in the project zone and selling them at the Bakel market. The fact that the Bakel market seems to be presently supplied by Mauritanian cattle has prompted this action.

The program has concentrated its actions in the Mbaniou Zone. However, as discussed in Chapter 3, the zone with the greatest degradation is the northern Ololdou Zone. One way to destock the livestock from this zone would be to concentrate the commercialization program into this zone.

The commercialization program has also concentrated its efforts on the cattle rather than small ruminants or other livestock (except for "Operation Tabaski" which deals with sheep and occurs once each year during the Muslim holiday). Given the role of small ruminants in supplying meat, it is recommended that more efforts be put into designing an appropriate commercialization program.

4.4. FEED SUPPLEMENTATION AND VETERINARY SERVICES

The veterinary services provided by the project are one of the more effective actions to date. The fact that the project population are regularly buying drugs and allowing the project's technical agents to vaccinate their cattle attests to the success of this program.

However, the classic struggle between veterinarians and range managers still exists in the project area. The success of the veterinary program means a faster rate of increase in the number of livestock in the zone. If this increase surpasses the productivity of the range resources, then serious overgrazing of all of the range may ensue. This does not mean that investment in the veterinary services should be reduced. It means that much more investment needs to be made in improving the range resources.

Another shortcoming is the fact that the veterinary services have concentrated on the cattle as opposed to small ruminants. A part of this is due to the fact that the training of the agents emphasized cattle. But another part is that small ruminants are the responsibility of women. More often than not, the technical agents do not, or cannot, talk

to the women in the villages. It is recommended that the agents work more closely with the women's program of the Rural Family Extension Service (Maison Familiale Rurale - Volet Feminin) to resolve this problem.

The project's supplementation program started in 1983 in the Mbaniou Zone with peanut-cake meal and salt blocks. In 1983 the project changed its program to include cotton seed, which is more easily available from Tambacounda and CMV (Complex Mineral Vitamin). These were made available to all three zones of the project area at full cost. This supplementation is intended for the milking cows in the villages. But observations show that the people will tend to put the feed in a basin to which all livestock have access. Given the fact that there are no cattle barns nor other form of control of the animals, the milking cows tend to be pushed aside by the larger bulls and oxen. Therefore the supplementation program is not having its maximum impact. The milk production survey (section 3.3.1.) did not show a statistical difference between the cows that are supplemented and those that are not.

The project's extension program, as well as the functional literacy program should concentrate more on helping people to feed their milking cows. The difficulty in separating cows from bulls is a physical constraint that may be solved through the herd stratification plan (discussed in the Range Management Plan).

The project should also consider other supplementation programs, such as that of small ruminants or poultry. In addition, the supplementation program in the Senegal Basin area should consider the rice residue that is available from the SAED irrigated fields along the Senegal and Falamé Rivers. This is a rich supplemental feed for large and small ruminants and is locally available. Finally, as mentioned in section 3.3., the project should encourage a more efficient use of sorghum and millet residue by reserving these for the end of the dry season.

4.5. IMPROVED WOOD STOVES AND BIOGAS GENERATORS

The Maison Familiale Rurale of the project has been instrumental in introducing two technologies that potentially could save on fuelwood consumption in the project zone. The first is a design for an improved wood stove, Banaksuf. These stoves are made from adobe, and are estimated to save on 50-30% of the fuelwood consumed by the cooking fires. In the dry season (1983), a team of technicians installed these stoves and trained the people in their use and maintenance. However, after one year, an evaluation team observed that the stoves had been a failure. The women of the villages had not been using them; without proper maintenance most of the stoves had succumbed to the rain, wind, or

goats' hooves. They concluded that the main problem was the lack of proper extension and time that would be required to convince the people (especially women) of the benefits.

The second appropriate technology was introduced in dry season 1984. This consisted of a medium-sized biogas (methane) generator that was installed in the field-base of the Maison Familiale Rurale in Ndiya, and a smaller, one-household generator installed in one of the project villages. By October 1984 both generators were functioning well. The larger generator supplied enough gas for a lamp and two stove outlets. The smaller generator produced enough for a lamp and one stove outlet. The lamp was used every night and was greatly appreciated by the villagers, but the women did not use the stove outlets. They felt that it did not give them the flexibility in flame-size that their traditional system provided.

It appears that with proper extension work, especially emphasizing the needs of women, either of these techniques could become acceptable. The biogas generators are probably more effective than the wood stoves and would last longer. The biogas generator built in the village cost 120,000 FCFA, which is essentially the price of two young bulls.

4.6. FUNCTIONAL LITERACY AND EXTENSION SERVICES

This is probably one of the best aspects of the project's activities. The literacy program is very well received by the people (although women tend to be underrepresented). In the three years of its operation, it produced many graduates, some of whom could execute the complicated research and survey tasks given to them by the range manager. It is recommended that the project expand its postliteracy program by hiring the graduates as researchers for the project and start a "community newsletter" that would help other graduates maintain their proficiency.

The extension services, along with the functional literacy campaign, are the backbone of the project's development efforts. None of the programs proposed in this report can be implemented without a strong extension program. Even though the project so far has done an excellent job, it is clearly not enough. With the expansion of the project into different programs, the extension staff and their resources should be increased. In addition, the agents should be trained in aspects other than veterinary services (such as human health, community organization and management, hydrology and range management) so that they can effectively extend the literacy themes dealing with those subjects. One training session was held by the range manager in July 1984 and showed that the agents are very eager for this type of information.

4.7. PASTORAL UNITS

The original project design called for the establishment of pastoral units (Unites Pastorales or UP) in the project zone. The UPs would theoretically be responsible for the management, exploitation and improvement of the range resources within the boundaries assigned to them. By the end of 1984, the villages of the Mbaniou Zone had been organized into four UPs. Each UP was composed of one to four villages. Two delegates from each village were elected for the planning committee of the UP (Comité de Gestion) who elected their president, vice president, secretary and treasurer. An umbrella organization, composed of elected delegates from all UPs in the Mbaniou Zone was also created (Association de Développement Pastoral, or ADEP) which is responsible for overall coordination between UPS.

In 1983, two surveys were carried out by the range manager in the entire project zone. One survey was designed to determine the existing socio-politico-economic affiliations between villages. The purpose of this survey was to help the project decide which villages could be grouped into UPs.

The other survey, conducted at the same time, was designed to determine the traditional pasture utilization patterns by each village (i.e., seasonal movements within the project area as well as transhumance to outside the area). This survey produced a list of pasture names (located on the base map, see Appendix F.) and a listing of pastures traditionally claimed by each village.

Based on the above information, the range manager presented a final technical document in July 1984 which provided recommendations on the restructuring of the UPs in the Mbaniou Zone, and the creation of new UPs in the Ololdou Zone and Sintiou Fissa Zone. There are now a total of 14 UPs proposed for all of the project zone. These recommendations are repeated in Appendix E. of this report.

The UPs are a fairly radical departure from the traditional social structures existing in the project zone. Apart from communal hunting parties, there is no other tradition of cooperation among villages. Furthermore, a modern organizational structure has been imposed on the UPs so that there is a linear hierarchy of president, vice president, secretaries, and treasurers, etc., which has no traditional precedence. Finally, two representatives to the planning committee of the UPs are elected from each village. However, only two out of these 24 representatives are village chiefs. All the rest are younger members of the chief's household. Given all these nontraditional actions, it is not surprising that the development of UPs, at least in terms of its social impact, is progressing so slowly.

For the UPs to begin to function, three crucial problems need to be resolved. In the first place, the establishment of the UP boundaries presupposses the existence of some form of land tenure legislation that would give ownership and responsibility of the land to the UP. Unfortunately such legislation does not yet exist. The national "Direction Amenagement de Territoire" of the Ministry of Interior is currently implementing the system of rural communities (Communauté Rurales) in eastern Senegal. Once these are established, the UPs will become the link between the people and the rural communities. Furthermore, some work is being done at the national level on establishing a Sylvo-Pastoral Code (Code Sylvo-pastoral), a constitution on the management of range and forest resources. Both of these actions, the code and the rural communities, are necessary steps before the UPs in the project zone can be given any legitimacy.

In the second place, most of the UPs still require some water-point development before they can become self-containing. Until such development, no one can be expected to respect the boundaries nor the Range Management Plan.

Finally, the project's extension program needs to put more time and patience on discussing the concept, principles and objectives of the UPs with the people. The proposals for establishing the boundaries around pastures should be reviewed with the people before they are finalized. In addition, various communal projects, such as cleaning ponds or firebreaks, building huts at camp sites, etc., can be envisaged and implemented at the UP level. These communal efforts will not only establish a precendent for future communal work, but will also be a catalyst for bringing to light social and political problems which then can be resolved within the UP.

During the time that it will take to design, finance and implement a new water development program, the project's extension program must concentrate on developing fully functional pastoral units. Only then can we expect the people, both within and outside the project zone, to understand and respect geographical boundaries.

4.8. CONCLUSIONS AND RECOMMENDATIONS

The water catchment ponds built in the Gambia Basin area have only partially fulfilled their main objectives. However they are potentially very appropriate to the range situation and to the system of livestock husbandry in the area. It is recommended that the water development strategy in the Gambia Basin incorporate two important aspects. The first is further investment in improvement of the ponds (to reduce infiltration and evaporation rates). The second is the organization of a water

development committee in each pastoral unit who would be responsible for the use, improvement and maintenance of the ponds.

The water development strategy for the Senegal Basin area recognizes the different constraints facing this area and recommends further studies on alternative water-point schemes especially other water-harvesting techniques. It also recommends the organization of a water development committee in each UP in the Senegal Basin area.

The efforts of the project to date in controlling bush fires has not been very successful. It is recommended that the Project should concentrate on attacking the causes of bush fires by continuing the extension program's antifire themes, and by devising appropriate ways to gether honey or hunt wild animals that would not require smoke.

The extent of bush fires is so vast that even if the fire brigades were extremely organized, they couldn't physically reach all parts of the range in time. On the other hand, a more efficient system of firebreaks could contain most of the fires. However, more firebreaks would be the solution only if a way was found to clean the lanes every year using local resources. The project should put more effort in designing an effective firebreak cleaning method.

The commercialization program, after a very slow start, may be potentially useful in helping the people benefit more from the sale of the livestock. This program should concentrate its efforts in the northern Ololdou Zone so as to help destock the excess livestock from the area. It should also put a new emphasis on commercializing small ruminants.

The veterinary services of the project have perhaps been too successful. In order to prevent an imbalance of livestock numbers and range resources in the immediate future, the project should concentrate more resources into improving rangelands.

The supplemental feed program to date has shown that people are willing to supplement their livestock's diet. The project should emphasize the supplementation of milking cows. In addition the possibility of cooperating with the SAED irrigated rice perimeters in order to obtain rice residue should be contemplated.

The project's social services program has been active in testing various appropriate technologies, the most promising of which are the biogas generators. The project should incorporate this technology into a larger extension program.

The extension services and functional literacy program are one of the most important and successful programs of the project. Many of the proposals contained in this and other reports would not be feasible without such an extension backbone. However, the service should be expanded not only in terms of the level of its staff and resources, but also in

terms of diversifying into other extension topics such as rangeland hydrology, and new organizational/managerial concepts.

The pastoral units could potentially be a useful institutional framework for the management of communal resources. However, after three years they still exist only on paper. The project should radically change its existing program and adopt a more active, institution-building strategy. It should also emphasize more discussions with the people on the principles and praxis of the UPs, and should organize communal work situations. Finally, the project should try to press the Government to draft and implement the Rural Community and Sylvo-Pastoral Codes which would provide the legal justification for the existence of the UPs.

5. PRELIMINARY RANGE MANAGEMENT PLAN

The preliminary Range Management Plan (RMP) is a synthesis of research activities and discussions with project personnel and villagers. The purpose of this plan is to provide guidelines for the management of livestock range and water resources by the people of the project zone. The guidelines are primarily aimed at preventing further degradation of the rangeland, and at improving the productivity of the livestock. The role of the project would be to extend the plan to the people, and to assist with financial and technical resources wherever necessary. The plan incorporates three organizational levels that currently exist in the project zone: herders, villages and pastoral units.

5.1. HERDS AND HERDERS

At this level, the plan concentrates on providing guidelines on improving the use of the rangelands. The Range Management Plan, as a whole, presupposes that the herds will be guided year-round by a herder, otherwise none of the plan's proposals could be implemented. The role of the project's extension services is indispensible in this regard. They can either encourage the younger generation in the villages to herd the animals or they can encourage the herd owner to hire a professional herder permanently.

In order to encourage an institution of herding, the project can do at least two things. The first is to make the job of the herder more comfortable by encouraging the use of horses or donkeys by the herder, or by suggesting and assisting in the construction of permanent huts at the more important camp sites.

The second is to establish training courses aimed not only at potential herders, but also at convincing the herd owners to take on permanent herders. The training course should be made official by granting professional "Herding Diplomas" to the graduates, and should cover at least six months of theoretical, as well as field-level, studies. The theoretical studies should emphasize the problems created by environmental degradation and the role of livestock in causing this degradation (the research results in sections 3.4.4. and 3.6.1. should be used here). The consequences of degradation, the role of the herder in preventing it, and the potential benefits from herding should also be discussed.

The practical studies should discuss the research findings on rangeland productivity ~~and demonstrate the logic of seasonal use linked to seasonal productivity (see sections 3.4.~~ and 3.5.). It should also promote the "early warning system" for monitoring overgrazing and condition of the range (see section 3.3.4.).

5.2. VILLAGES

In order to prevent the concentration of animals around the villages, the RMP calls for a stratification of the village herd into a "bush herd" and a "milk herd." The milk herd would be composed of the milking cows and their calves, and a few draft oxen. These animals, along with the equines and small ruminants, would be kept permanently at the village. An approximate 5 km-radius around the village would be reserved exclusively for them. They would water at nearby natural ponds or the well, and would receive supplemental feed and minerals.

The bush herd would be composed of the remainder of the cattle (heifers, pregnant cows, bulls, etc.), and they would be guided by a herder to camps. Whenever a pregnant cow dropped her calf, she would be returned to the village and dry cows and their calves would be taken to the camps. Otherwise the bush herd would remain on the range all year, moving from one pasture to the next.

The idea of stratifying the herds is not new. Certain pastoral groups in Africa (such as the Dinka of the Sudan) have been practicing it for thousands of years, but it is a new idea for settled agropastoral groups such as the Toucouleur. However, it is an idea that is not too much beyond the existing husbandry system. Already the animals are herded to distant camps even though it is only for the protection of fields. In addition, if the owner is forced to send his cattle on transhumance to Mali because of the lack of water in the village well, he will try to keep a few milking cows for the household's needs. Finally, the herd stratification strategy relies on a relatively cheap resource: the herder. Fencing off the pastures into grazing blocks would achieve the same results, but fences are beyond the people's financial resources.

One constraint to the success of the stratification strategy is the fact that the water catchment basins built by the project do not outlast the dry season. Therefore, the bush herd would be forced to return to the village well when the water-points dried up. If the water development strategy discussed in section 4.1. is implemented, then the constraint may be eliminated. In the meantime, the bush herd would be allowed to return to the village when existing ponds dry, but they would be taken back again with the first rains of the season. Therefore, they would be spending at least 6-8 months of the year away from the village. It is expected that this reduction in the grazing pressure around the villages would help to prevent further soil degradation. In addition, it is expected that the greater forage availability for both the bush and milk herds, as well as a decrease in the distance that they have to walk everyday, would result in significant increases in live-weight and milk production.

Other programs at the village level should include certain improvements in the cultivation/livestock interaction (discussed in section 3.3.4.) such as better manure utilization techniques (especially if the majority of the herd is to be kept permanently away), fallow/crop rotation systems, and better maintenance of fences around the fields.

Finally, the revegetation of denuded areas should be organized at the village level since 90% of the denuded areas are in the radius of individual villages. The project should encourage the formation of working parties, village nurseries and seed multiplication plots. The women should also be included in this program.

5.3. PASTORAL UNITS

The pastoral units (UP) are the only institution that can be used to manage the more communal, extravillage, resources, such as water-points and firebreaks. One cannot expect the project to continue to manage them, nor can one expect the government to take over the responsibility.

Therefore, the project must concentrate its efforts on establishing the institutional legitimacy and framework of the UPs. In addition the UPs must be assisted by the project so that they can take over the responsibilities of organizing communal work. At the moment, the most important communal actions that could be done are the water development strategy (discussed in section 4.1.), the cleaning of firebreaks and control of bush fires (section 4.2.), and the improvement of rangelands through reseeding with perennial grasses and legumes (section 3.6.).

Once the Government has established the UPs' legitimacy of land tenure, the project can begin to emphasize the land use implications. The concept of "grazing or watering permits" and the fact that these permits apply to the use of their range by both neighboring UPs and nomads, must be discussed with the people. The two hurdles to implementing a permit system (social inacceptability and lack of physical means of supervision and control) should also be discussed, but it will have a better chance of resolution if the rural communities are established and if the Sylvo-Pastoral Code incorporates the concept of permits.

5.4. CONCLUSIONS AND RECOMMENDATIONS

The main purpose of the Preliminary Range Management Plan (RMP) is to provide guidelines on the management of range resources by the people of the project area, with

the immediate objectives of preventing (and controlling) rangeland degradation, and improving the productivity of the livestock.

The RMP proposes a series of programs aimed at three different organizational levels: the herder/livestock owner, the village, and the pastoral unit. The project's role would be one of encouraging the adoption of certain improvements in the traditional animal husbandry and range exploitation system, the details of which must be filled in by collaboration with the people. The adoption of all aspects of the RMP cannot be expected very soon. However, the RMP's simplicity, and the fact that the programs at each level can be implemented independently of each other, suggest that the failure of one aspect of the plan does not necessarily jeopardize any other aspect. The task of the project should be one of being sensitive to people's reactions, and should take each step forward at its own pace.

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APPENDICES

APPENDIX A.

SOIL ANALYSES AND VEGETATION INVENTORY DATA

TABLE A1.

SUMMARY OF SOIL TESTS IN THE BAKEL PROJECT ZONE, 1983/84

Sample Code & Horizon	Soil depth cm	% Gravel	as % of nongravel matter				pH	Expressed as meq/100g					% Total Organic Matter	% Total N	Ratio C/N
			Sand	Silt	Clay	Texture[a]		Na^+	K^+	Ca^+	Mg^+	CEC			
1 A	0-22	20-50	75	8	17	GL									
C1	22-47	partially hardened ironstone													
C2	47+	solid ironstone with discontinuous pores													
2 A	0-16	20	78	7	15	SL									
B	16-41	20	67	10	23	SCL									
C1	41-70	20	55	13	32	SCL									
C2	70-130	20	60	12	28	SCL									
C3	140+	20	51	14	35	SCL									
3 A	0-10	1	60	40	0	SL	5.5	0.3	0.4	1.6	0.15	2.62	0.14	0.07	11.71
B	10-30	1	28	58	14	SiL	7.1	0.5	0.45	7.75	1.18	10.05	0.11	0.05	13.08
4 A	0-20	T	66	34	0	SL	5.6	0.1	1.2	1.00	0.3	2.77	0.1	0.5	11.60
B	20-40	T	49	51	0	SiL	5.2	0.07	1.0	0.6	0.08	2.63	0.14	0.06	13.64
5 A	0-12	0	35	53	12	SiL	6.3								
B	12-32	0	33	45	22	L	5.0								
C1	32-72	20	23	28	49	C	4.9								
C2	72+	20	23	26	51	C	5.0								

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TABLE A1. (con't.)

Sample Code & Horizon	Soil depth cm	% Gravel	as % of nongravel matter				pH	Expressed as meq/100g					% Total Organic Matter	% Total N	Ratio C/N
			Sand	Silt	Clay	Texture[a]		Na^+	K^+	Ca^+	Mg^+	CEC			
6 A	0-20	3.55	68	32	0	SL	7.5	0.05	2.50	4.90	0.23	7.85	0.32	0.14	13.35
7 A	0-10	14.34	64	36	0	SL	7.2	0.10	1.2	2.20	0.66	4.33	0.14	0.07	11.71
8 A	0-15	6.73	67	33	0	SL	6.3	0.05	0.2	1.7	0.57	2.69	0.20	0.14	8.36
B	15-35	35.6	66	34	0	GSL	5.7	0.1	0.6	0.9	0.72	2.67	0.14	0.07	11.71
9 A1	0-1	0	45	36	19	L	6.2								
A2	1-20	0	45	34	21	L	5.5								
B	20-?	20	29	20	51	C	4.8								
10 A	0-35	50	60	40	0	VGSL	6.2	0.05	0.2	1.8	0.6	3.00	0.24	0.05	15.55
C	35+	solid ironstone													
11 A1	0-10	72	31	44	25	VGL	6.7								
A2	10-30	66	27	40	33	VGCL	5.2								
C	30+	solid ironstone													
12 A	0-20	4	27	40	33	CL	5.0								
C	20+	solid ironstone													
13 A	0-23	T	51	49	0	SL	5.7	0.1	0.1	1.4	0.05	2.21	0.14	0.07	11.71
B	23-46	T	48	52	0	SiL	5.2	0.2	0.1	1.3	0.58	2.88	0.14	0.03	27.33
14 A	0-30	T	77	23	0	LS	5.9	0.1	0.1	1.7	0.12	2.19	0.18	0.07	15.0
B	30-40	T	77	23	0	LS	5.6	0.05	0.05	1.1	0.39	1.76	0.1	0.07	8.28

TABLE A1. (con't.)

Sample Code & Horizon	Soil depth cm	% Gravel	as % of nongravel matter				pH	Expressed as meq/100g					% Total Organic Matter	% Total N	Ratio C/N
			Sand	Silt	Clay	Texture[a]		Na^+	K^+	Ca^+	Mg^+	CEC			
15 A1	0-4	0	71	13	16	SL	6.9								
A2	4-25	0	51	25	24	SCL	5.1								
B	25+?	0	45	21	34	SCL	5.1								
16 A	0-26	0	63	20	17	SL	6.1								
B1	26-54	0	65	13	22	SL	5.8								
B2	54+?	0	63	13	23	SCL	5.5								
17 A	?	0	41	46	13	L	6.7	0.13	0.53	15.4	3.3	21.4	1.12	0.06	10.8
B	?	5	35	45	20	L	7.4	0.11	0.71	15.0	3.5	19.8	0.79	0.05	9.2
18 A	?	0	61	28	11	SL	6.6	0.08	0.55	10.8	2.8	16.1	1.05	0.06	10.2
B	?	0	58	23	19	SL	7.1	0.21	0.47	9.8	3.1	15.5	0.33	0.02	9.5
C1	?	0	59	13	28	SCL	7.1								
C2	?	0	61	13	26	SCL	7.2								
19 A	?	0	75	20	5	LS	6.6	0.14	0.56	8.6	1.1	11.6	0.5	0.02	14.5
B	?	0	50	34	16	L	6.9	0.05	0.23	8.0	1.6	12.2	0.16	0.03	
C	?	0	50	35	15	L	6.7								
20 A	?	0	78	18	4	LS	6.4	0.06	0.47	6.5	1.0	9.5	0.93	0.05	10.8
B	?	0	71	18	11	SL	6.2	0.07	0.32	6.1	1.2	10.0	0.26	0.01	10.7
C	?	0	51	18	31	SCL	6.1								

TABLE A1. (cont.)

Sample Code & Horizon	Soil depth cm	% Gravel	as % of nongravel matter				pH	Expressed as meq/100g					% Total Organic Matter	% Total N	Ratio C/N
			Sand	Silt	Clay	Texture[a]		Na^+	K^+	Ca^+	Mg^+	CEC			
21 A	?	0	24	26	50	C	6.1	0.29	0.92	13.5	6.2	23.7	0.47	0.03	9.0
B	?	0	22	31	47	C	6.0	0.48	0.62	15.6	6.9	26.3	0.47	0.02	13.5
C1	?	0	20	30	50	C	6.1								
C2	?	3	47	18	35	SCL	7.3								

SOURCE: Profiles 1 and 2 are from the Soils/Water Engineering report; profiles 3, 4, 6, 7, 8, 10, 13 and 14 were analyzed by Soil Laboratory of SAED, Ross Bethio, Senegal; profiles 5, 9, 11, 12, 15 and 16 were analyzed by Soil Testing Laboratory, MSU, East Lansing, Michigan, USA; profiles 17-21 are from Nevini (1983).

NOTES: [a]Abbreviations; VG = very gravelly; G = gravelly; S = sandy; Si = silt; L = loam; C = clay.

TABLE A2.

RANGE INVENTORY DATA: BIOMASS STUDIES (all figures in g-DM/m^2)

Range Type	Site	September 1983			May 1984			September 1984			
		Monocot	Dicot	Total	Standing Herb	Herb Litter	Total Herb	Woody Litter	Monocot	Dicot	Total
Ironstone	N1	432.42	42.3	474.72	21.82	75.18	97.22	36.28	83.46	14.28	97.74
	N2	358.46	68.72	427.18	20.18	75.42	95.6	37.64	159.78	51.22	210.1
	N3	151.78	27.62	179.4	3.8	55.28	59.08	19.16	77.4	1.14	78.54
	N6	?	?	319.62	5.1	32.66	37.76	19.5	67.54	6.62	74.16
average	N	304.22	46.0	350.22	12.72	59.64	72.36	28.14	97.04	18.1	115.14
Floodplain (Gambia)	V1	104.74	35.88	140.62	10.88	70.42	81.3	25.18	64.14	36.34	100.48
	V2	115.8	64.82	180.62	35.16	69.56	104.66	25.0	80.18	12.16	92.34
	V3	161.78	2.4	164.18	?	?	?	?	95.9	7.84	103.74
	V4	122.74	145.8	268.54	41.38	18.02	59.4	16.0	66.84	26.62	93.46
	V6	?	?	?	?	?	?	?	13.4	10.3	23.7
average (exclude V6)	V	126.26	62.24	188.5	29.14	52.64	81.78	19.4	76.76	20.74	97.5
Floodplain (Senegal)	P2	231.12	12.7	243.82	5.8	55.82	61.62	7.2	98.08	13.34	111.42
	P3	238.28	8.76	247.04	site burnt			204.96	20.74	225.7	
average	P	234.7	10.74	245.44					151.52	17.04	168.56
Degraded (Senegal)	P1	20.26	48.78	69.04			0	0	3.86	4.08	7.94
Degraded (Gambia)	S1	13.0	7.42	20.42			0	0	0.34	0.2	0.54
	S2	0.48	2.86	3.34			0	0	?	?	?
	S4	5.08	4.86	9.94			0	0	7.02	1.02	8.04
	S5	13.66	12.64	26.3			0	0	4.16	13.22	17.38
	S6	2.4	4.5	6.9			0	0	2.18	5.78	7.96
average	S	6.92	6.46	9.94			0	0	3.42	5.06	8.48

TABLE A2. (con't.)

Range Type	Site	September 1983			May 1984			September 1984			
		Monocot	Dicot	Total	Standing Herb	Herb Litter	Total Herb	Woody Litter	Monocot	Dicot	Total
Hill	C1	80.14	25.02	105.16	9.88	18.94	28.2	35.6	41.06	25.3	66.36
	C2	211.04	2.92	213.96	9.18	47.66	56.84	25.16	38.2	7.24	45.44
	C3	216.52	14.58	231.1	site burnt			70.62	7.86	78.48	
average	C	169.24	14.16	183.4	9.54	32.98	42.52	30.38	49.96	13.46	63.42
Foothill	E1	221.42	42.0	263.42	18.6	121.28	139.88	T	21.22	62.9	84.12
	E2	112.18	272.42	384.6	site burnt			?	?	?	
	E3	319.12	10.96	330.08	site burnt			66.58	0.64	67.22	
average (exclude E2)	E	270.28	26.48	296.75					43.9	31.78	75.68
Streambed (Gambia)	R1	152.68	71.66	224.34	?	?	?	?	71.4	21.76	93.16
	R2	164.64	52.52	217.16	?	?	?	?	92.64	28.2	120.84
	R3	201.54	161.56	363.1	?	?	?	?	206.26	46.78	253.04
	R6	326.46	166.04	492.5	14.46	143.28	157.74	32.1	257.1	68.06	325.16
average	R	211.34	112.94	324.28					136.86	41.2	198.06
Swamp	D1	79.68	37.62	117.3	site burnt			133.4	4.32	137.72	
	D2	112.18	268.42	380.6	site burnt			?	?	?	
	D5	69.5	83.44	152.94	site burnt			256.48	14.94	271.42	
	D6	161.72	18.98	180.7	site burnt			143.94	1.96	145.9	
average	D	105.78	102.1	207.88					177.94	7.08	185.02

SOURCE: Survey data.

TABLE A3.

RANGE INVENTORY DATA: POINT CENTER QUARTER METHOD - 1983:
IMPORTANCE VALUES OF TREES AND SHRUBS BY RANGE TYPE

	Ironstone	Floodplain (B)	Floodplain (S)	Degraded (G)	Hill	Foothill	Streambed	Swamp
Aca ada			1.51					
Aca mac	42.99	2.37			64.08			12.89
Aca sen		2.29	4.63	18.57		2.41		
Aca sey	2.14		62.36	16.67	13.25	4.45	1.58	
Ada dig			51.91				23.37	30.71
Ade obe		3.38	4.24	16.09	15.14			
Ano lei						10.37	11.22	
Bal aeg		0.46	27.25	4.50	10.68			
Bom cos	8.40	6.19	2.87					11.07
Bor aeth							5.97	
Bos ang	1.91	0.78						3.72
Bos sal						2.53		
Bos sen		4.49		27.03				1.41
Cad far	6.54							1.37
Cas Sieb		2.68						4.05
Car edul								1.43
Com acul	7.86							
Com geit	23.55	6.59	1.11		20.21			11.77
Com glut	57.78	96.28	17.71		62.63	116.82	33.42	59.96
Com mic	7.72	10.42	40.03	6.54	18.93		20.92	6.82
Com nig	23.89	17.54	11.24	3.09	36.57	4.35	18.47	39.68
Comm afr					8.52			2.96
Cor sin						0.83		
Dal mela								7.79
Dic glom		2.02	8.43	6.47	5.01	1.72	5.61	
Fer apon		3.70	23.79	2.73			7.02	14.28
Fic iteo						0.87		
Gar tern	2.38							
Gre bic	28.07	26.62	15.57	36.35	2.04	21.31	4.53	23.62
Gre fla		0.77		7.91				1.37
Gui sen	57.84	48.25	9.86	34.45	5.20	76.53	60.2	20.95
Lan acid			3.28			39.5		
Lan velu				4.89				
Mit ine							4.07	
Orm bib						1.11		
Ostr stu	2.45	1.21			10.23		7.66	3.71
Pil ret							6.42	
Pter eri					10.7		21.95	7.04
Pter luc	20.5	29.19	4.46	32.65	14.95		12.48	16.18
Scl bir		2.24	6.09				30.07	7.59
Sec vis	2.01							
Ster set		26.26		69.59		11.31		5.75
Stro sar							2.5	
Stry spi		3.4						
Ziz mau			4.62			5.94		1.58

SOURCE: Survey data.

TABLE A4.

RANGE INVENTORY DATA: POINT CENTER QUARTER METHOD - 1983:
PERCENT RELATIVE DENSITY OF TREES AND SHRUBS BY RANGE TYPE

	Ironstone	Floodplain (B)	Floodplain (S)	Degraded (G)	Hill	Foothill	Streambed	Swamp
Aca ada			0.13					
Aca mac	17.52	0.95			27.9		5.12	5.6
Aca sen		0.89	0.38	4.59		0.75		
Aca sey	0.68		37.40	1.89	7.0	1.3	0.23	
Ada dig			0.25				0.23	0.6
Ade obe		0.91	1.31	3.8	0.4			
Ano lei			0.13			0.45	1.2	
Bal aeg		T	8.96	0.83	3.8			
Bom cos	1.82	2.57	1.06					3.7
Bor aeth							0.46	
Bos ang	0.68	0.32						1.2
Bos sal						0.45		
Bos sen		0.98		6.46				0.6
Cad far	2.98							0.6
Cas Sieb		0.28						1.2
Car edul								0.6
Com acul	2.71							
Com geit	8.18	2.19	1.06		5.4			5.0
Com glut	17.18	41.03	8.51		28.9	55.3	13.55	23.1
Com mic	2.69	1.48	9.57	2.25	0.9		8.6	2.5
Com nig	8.4	8.04	5.32	0.71	5.2	0.4	2.53	15.6
Comm afr					4.9			0.6
Cor sin						0.15		
Dal mela								1.2
Dic glom		1.11	4.25	1.75	3.3	0.35	3.6	
Fer apon		2.21	12.61	0.2			2.98	5.6
Fic iteo						0.15		
Gar tern	1.14							
Gre bic	4.71	5.53	3.81	5.69	0.4	1.55	2.57	8.7
Gre fla		0.3		2.74				0.6
Gui sen	27.47	23.67	2.76	1.45	1.7	34.4	40.1	11.9
Lan acid			0.13			3.7		
Lan velu				1.12				
Mit ine							0.65	
Orm bib						0.15		
Ostr stu	1.15	0.32			5.4		2.33	1.9
Pil ret							0.92	
Pter eri					3.3		2.53	1.9
Pter luc	0.68	1.66	1.06	6.40	1.3		3.87	1.9
Scl bir		0.62	1.06				2.85	1.9
Sec vis	0.67							
Ster set		0.82		47.65		0.15		0.6
Stro sar							0.46	
Stry spi		1.25						
Ziz mau			1.31			0.8		0.6

SOURCE: Survey data.

TABLES A3. AND A4.

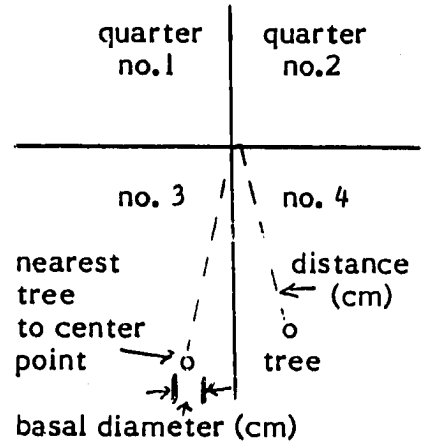
NOTES

Calculations for Point Center Quarter (PCQ) Method of Measuring Trees and Shrubs

basal area = (basal diameter)^2

mean distance = $\frac{\text{total distance}}{\text{total no. quarters}}$

absolute density = $\frac{10{,}000\ m^2}{\text{mean distance}}$



relative density = $\frac{\text{No. ind. of one species}}{\text{No. ind. in all species}} \times 100$

relative frequency = $\frac{\text{frequency per species}}{\text{sum frequency of all species}} \times 100$

relative dominance = $\frac{\text{total basal area of one species}}{\text{total basal area of all species}} \times 100$

importance value = relative density + relative frequency + relative dominance

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APPENDIX B.

SIGHTINGS OF BIRDS AND MAMMALS IN THE PROJECT ZONE

TABLE B1.

BIRDS SIGHTED IN THE PROJECT ZONES*

HERONS AND HAMMERKOP				
English name	Latin name	French name	Location	Time of Year
Black-headed Heron	Ardea melanocephala	Heron Melanocephale	Sinthiou Fissa Zone and Bakel: Just outside Sinthiou Fissa	May and January
Purple Heron	Ardea pupurea	Heron Pourpre	Bakel: Perimeters	January
Hammerkop	Scopus umbretta	Ombrette	Ololdou and Sinthiou Fissa Zones: Near Kidira, Woubowol, Bema and Seme	February
VULTURES AND BATELEUR				
English name	Latin name	French name	Location	Time of Year
Nubian Vulture	Aegypius tracheliotus	Oricou	All three zones: Very common	
Ruppell's Griffon Vulture	Gyps ruppellii	Vautour de Ruppell	Mbaniou zone	
White-backed Vulture	Gyps begalensis	Gyps Africain	Mbaniou Zone: Mbaniou Bakel road	April
Bateler	Terathopuis ecaudatus	Bateleur	Mbaniou Zone: Near Toulekedi All three zones: Very common	April

*This is a list of birds sighted and identified by the socioeconomist. This list was compiled through casual observation in the area and provides only a small sample of the bird population.

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TABLE B1. (continued)

BIRDS OF PREY				
English name	Latin name	French name	Location	Time of Year
Palid Harrier	Circus macrourus	Busard Pale	Mbaniou Zone Road from Mbaniou to Waly Diala	February
West African Goshaw	Accipiter toussenelii	Autour Tachiro	Sinthiou Fissa Zone: Road from Sinthiou Fissa to Arigabo	May
Lizard Buzzard	Kaupifalco monogrammicus	Buse Unibande	Ololdou Zone: Near Ololdou	May
Swallow-tailed Kite	Elanus ricourii	Naucler d'Afrique	Mbaniou Zone: Mbaniou road	May
FRANKLIN AND GUINEA-FOWL				
English name	Latin name	French name	Location	Time of Year
Latham's Franklin	Francolinus lathami	Francolin de Latham	All three zones: Very common	
Grey-breasted Helmeted Guinea-fowl	Numida meleagris	Pintade Commune	All three zones: Quite common	
BUSTARDS				
English name	Latin name	French name	Location	Time of Year
Senegal Bustard	Eupodotis senegalensis	Poule de Pharaon	Ololdou Zone: Between Ololdou and the escarpment	January

TABLE B1. (continued)

Black-bellied Bustard	Eupodotis melangaster	Outade a Ventre Noir	Mbaniou Zone: Between Toulekedi and Ndia	March
DOVES				
English name	Latin name	French name	Location	Time of Year
Morning Dove	Streptoelia decipiens	Tourterelle Pleureuse	All three zones: Very common	
Red-eyed Dove	Streptoelia semitorquata	Tourterelle a collier	All three zones: Quite common	
Long-tailed Dove	Oena capensis	Tourterelle du Cap	All three zones: Very common	
PARROTS				
English name	Latin name	French name	Location	Time of Year
Senegal Long-tailed Parakeet	Psittacula krameri	Perruche a Collier	All three Zones: Quite common	
Senegal Parrot	Poicephalus seneglus	Youyou	All three Zones: Very common	
PLOVER				
English name	Latin name	French name	Location	Time of Year
Black-headed Plover	Vanellus tectus	Vanneau a Tete Noire	All three zones: Very common	
SANDPIPER				
English name	Latin name	French name	Location	Time of Year
Crocodile Bird	Pluvianus Aegyptius	Pluvian d'Egypte	Bakel: SAED perimiters	March

TABLE B1. (continued)

CUCKOOS AND COUCAL				
English name	Latin name	French name	Location	Time of Year
Emerald Cuckoo	Chrysococcyx cupreus	Foliotocol	Ololdou Zone	October
Senegal Coucal	Centropus senegalensis	Coucal du Senegal	All three zones: Very common	
ROLLER HOOPOE AND BEE-EATERS				
English name	Latin name	French name	Location	Time of Year
Roufus-crowned Roller	Coracias naevia	Rollier Varie	All three zones: Extremely common	
Hoppoe	Upupa epos	Huppe Fasciee	All three zones: Common	
Blue-cheeked Bee-eater	Merops superciliosus	Guepier de Perse	Mbaniou Zone: Mbaniou road	May
NIGHTJAR				
English name	Latin name	French name	Location	Time of Year
Plain Nightjar	Caprimulgus inornatus	Engoulevent Terne	All three Zones: Very common during rainy season at night	
HORNBILLS				
English name	Latin name	French name	Location	Time of Year
Red-headed Hornbill	Tockus erythrorhynchus	Petit Calo a Bec Rouge	All three zones: Extremely common	
Grey Hornbill	Tockus nasutus	Petit Calo a Bec Noire	All three zones: Very common	
Ground Hornbill	Bucorvus abyssinicus	Grand Calo d'Abyssinie	All three zones: Fairly common	

TABLE B1. (continued)

CROW				
English name	Latin name	French name	Location	Time of Year
Pied Crow	Corvus albus	Corbeau Pie	All three zones: Fairly common	
WARBLER BARBET AND WOODPECKER				
English name	Latin name	French name	Location	Time of Year
Striped Cisticola	Cisticola natalensis	Cisticole Striee	Bakel: Garden	March
Red-rumped Tinker-bird	Pogoniulus atroflavus	Barbu a Croupion Rouge	Ololdou Zone: Gourel Dialoube	August
Olivaceous Warbler	Hippolais pallida	Hypolais Pale	Bakel: Garden	March
Green-backed Woodpecker	Campethera caillautii	Pic a Dos Vert	Sinthiou Fissa: Between Sinthiou Fissa and Arigabo	February
SUNBIRD				
English name	Latin name	French name	Location	Time of Year
Mouse-brown Sunbird	Anthreptes gabonieus	Soui-manga Brun	Bakel: Garden	March
Beautiful Long-tailed Sunbird	Nectarinia pulchella	Soui-manga a Longue Queue	Bakel: Garden	April
SWALLOW AND SHRIKE				
English name	Latin name	French name	Location	Time of Year
Mosque Swallow	Hirundo Senegalensis	Hirondelle a Ventre Roux	Ololdou Zone: Kidira Bakel road near Bakel	May

TABLE B1.(continued)

Great Grey Shrike	Lanius excubitor	Pie-grieche Fiscale a Dos Gris	Sinthiou Fissa: Walli Diala to Arigabo road	April
ROBIN-CHAT				
English name	Latin name	French name	Location	Time of Year
Snowy-crowned Robin-chat	Cossypha niveicapilla	Petit Cossyphe a tete Blanche	Bakel: Garden	April
ESTRILDINE WEAVERS				
English name	Latin name	French name	Location	Time of Year
Red-cheeked Cordon Bleu	Estrilda bengala	Cordon Bleu	Bakel: Garden	February
Black-rumped Waxbill	Estrilda troglodytes	Bec de Corail Cendre	Bakel: Garden	March
Senegal Fire-Finch	Langonosticta senegala	Armarante Commun	All three zones: Very common	

TABLE B2.

LIST OF MAMMALS SIGHTED IN THE PROJECT ZONE

English name	Latin name	French name	Location	Time of Year
Red monkey	Erythocebus patas	Singe rouge	Ololdou Zone: Kidira Bakel road; a dozen or more	December
Green monkey	Cercopithecus aethiops callitriche	Cercopitheque	Ololdou Zone: Kidira Bakel road, arround ten	March
Baboon	Papio papio	Babouin	Ololdou and Sinthiou Fissa Zones: Kidira Bakel road and between Woubowol and Ourousoulé, in large groups of fifty or more	October to March
Galago	Galago senegalensis	Galago	Mbaniou Zone, many sightings with spotligts at night	May
Leopard	Panthera pardus	Leopard	Ololdou Zone: road to Sira Hamadi Bocar Kane. one at dusk	December
Lynx	Felis caracal	Lynx or caracal	Ololdou Zone: Near the Bakel air strip, one	November
Lybian wild cat	Felis libyca	Chat de libye	Mbaniou Zone: near Garala at night, one	May
Serval	Felis serval	Serval or chat-tigre	Mbaniou Zone at night, one	December

TABLE B2. (continued)

Fox	Vulpes pallida	Renard des sable	Mbaniou Zone: Bakel Mbaniou road at the escarpment, at night	April
Jackal	Canis adustus	Chacal a flancs rayes	In all Zones, quite common	
Hyena Corcuta	Crocuta	Hyene tachetee	Ololdou Zone: Kidira Bakel road near the Bakel, at night	May
Genette	Genetta tigrina	Genette	All three Zones at night	quite common
Egyptian mongoose	Ichneumia aegypticus	Mangouste d'Egypte	Mbaniou Zone: near Diare Mbolo at night	May
Mongoose	Ichneumia albicauda	Mangouse a queue blanche	Mbaniou Zone: Pond #1	March
Civet	Viverra civetta	Civette	Ololdou Zone; near Bakel	May
Ratel	Mellivora capensis	Ratel	Mbaniou Zone: at night near Diare Maboube	May
Wort hog	Phacocherus aethiopicus	Phacochere	All three Zones, fairly common	
Coba	Redunca redunca	Cobe redunca or nagor	Mabaniou Zone: Fire break from Diarel Mbolo to Seno Wandaly	February

TABLE B2. (continued)

Gazelle	Gazelle rufifrons	Gazelle a front roux	Mbaniou Zone: at night near Mbaniou	May
Oreby	Ourebia ourebi	Ourebi	Mbaniou Zone: at night near Mbaniou	May
Antilope*	Phalophus rufilatus	Cepahalophe a flancs roux	Mbaniou Zone:	
Puff Adder			Mbaniou Zone: near Diarel Maboube at night	May
Spitting cobra			Mbaniou Zone: Gourel Allen	

*Sighted by a member of the socio-economic team supervisory staff.

Note: Most sightings in May were done with Naturalist Dean Treadwell at night using spotlights.

APPENDIX C.

LIST OF PLANT SPECIES COLLECTED IN THE BAKEL LIVESTOCK PROJECT ZONE OCTOBER 1982 to OCTOBER 1984

TABLE C1.

LIST OF PLANT SPECIES COLLECTED IN THE BAKEL LIVESTOCK PROJECT ZONE[a]
October 1982 to October 1984

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
A:				
Acacia Adansonii G. & Perr.	Mimosoideae	tree	gawdi	clay
A. albida Del.	"	"	taski	loam;clay
A. ataxacantha D.C.	"	bush	gubi ndaneewi	ironstone
A. Ehrenbergiana Hayne.	"	tree	bulbi bodeewi	loam
A. macrostachya Reich.	"	bush	ciidi/gogoro	loam;clay
A. nilotica (Benth.) A.F. Hill	"	tree	gandi gaddé	loam;clay
A. raddiana Savi.	"	"	tiluki	loam
A. Senegal (L.) Willd.	"	"	patuki	sand;loam
A. sieberiana D.C.	"	"	aluki	sand
Acalypha ciliata Forsk.	Euphorbiaceae	annual forbe	kebel	ironstone
Acanthospermum hisbidum D.C.	Compositae	"	-	clay
Achyranthes argentea Lam.	Amaranthaceae	"	nakaberé	loam
Adansonia digitata L.	Bombacaceae	tree	bokki	loam
Adenium obesum (Forsk.) Roem.& SC.	Apocynaceae	"	darabokki	sand;loam
Aeschynomene Schimperi Hochst.	Papilionoideae	annual forbe	dengan	loam
A. tambacoundensis Berh.	"	"	hudo beeli	clay
Albizzia Chevalieri Harms.	Mimosoideae	tree	budawi	clay
Alysicarpus ovalifolius (S. & Th.) Leon.	Papilionoideae	annual forbe	jilé	sand;loam
A. rugosus (Willd.) D.C.	"	"	padgiri jawlé	sand;loam

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TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Ammania prieureana G. & Perr.	Lythraceae	annual forbe	naiko	sand;loam
Ampelocissus leonensis (Hook.) Planch.	Ampelidaceae	"	palpalel/kebbé	loam;clay
Andropogon Chevalieri Reznik.	Graminae	annual grass	-	rocky loam
A. fastigiatus S.W.	"	"	-	loam
A. Gayanus Kunth.	"	perrenial grass	dajal	clay;loam
A. pseudapricus Stapf.	"	annual grass	dajé calli	loam;ironstone
Anogeissus leiocarpus (DC)G. & Perr.	Combretaceae	tree	kojoli	clay;loam
Anticharis linearis (Benth.) Hochst.	Scrofulariaceae	annual forbe	-	loam
Aristida adscensionis L.	Graminae	annual grass	-	sand;loam
A. funiculata Trin. & Rupr.	"	"	-	sand
A. Kerstingii Pilger.	"	"	-	loam
A. longiflora Sch. & Thonn.	"	perrenial grass	sirin	sand
A. mutabilis Trin.	"	annual grass	celel	sand;loam;clay
A. stipoides Lam.	"	"	budel	sand
Asparagus africanus Lam.	Liliaceae	perrenial forbe	narari	ironstone
A. Pauli-Gulielmi Solms-Laub.	"	"	pelol fowru	loam;clay;ironstone
Aspilia helianthoides (S. & Th.) Oliv.	Compositae	annual forbe	niayko	clay
Azadirachta indica A. Juss.	Meliaceae	tree	neem	loam
B:				
Bacopa hamiltoniana (Benth.) Wettst.	Scrofulariaceae	annual forbe	kopi gelodi	loam;clay
Baissea multiflora A. DC.	Apocynaceae	liana	caala lombowi	ironstone
Balanites aegyptiaca (L.) Del.	Zygophyllaceae	tree	murtoki/soromtomo	loam;sand

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Bauhenia rufescens Lam.	Ceasalpiniodeae	bush	cumborki/nammaari	sand;loam
Bergia suffritucosa (Del.) Fenzl.	Elatinaceae	annual forbe	sinamungel	sand;clay
Blainvillea gayana Cass.	Compositae	"	-	clay
Blepharis linariifolia Pers.	Acanthaceae	"	borborongol	sand;loam
B. maderaspatensis (L.) Heyne	"	"	-	loam
Bombax costatum Pell. & Vuill.	Bombacaceae	tree	doy	ironstone;loam
Borassus aethiopum Mart.	Arecaceae	"	dubbé	clay
Borreria chaetocephala DC. Hepp.	Rubiaceae	annual forbe	-	loam;clay
B. filifolia (S. & Th.) K. Schum.	"	"	-	clay
B. octodon Hepp.	"	"	-	sand
B. radiata D.C.	"	"	giringal	sand;loam;ironstone
B. stachydea (DC.) H. & Dalz.	"	"	"	loam;clay
Boscia angustifolia A. Rich.	Capparidaceae	tree	tireewi	loam;clay
B. senegalensis (Pers.) Lam.	"	bush	gijilli	loam
Brachiaria deflexa C.E. Hubbard.	Graminae	annual grass	-	clay
Brachiaria distichophylla Stapf.	Graminae	annual grass	padgiri yambé	clay;loam
B. Hagerupii Hitch.	"	"	hudo badi	clay
B. ramosa Stapf.	"	"	-	rocky;loam
B. stigmatisata Stapf.	"	"	barawo	loam
B. stipitata Hubb.	"	"	-	clay
Bulbostylis barbata C.B.Cl.	Cyperaceae	annual sedge	balel ndanedi	clay;ironstone
B. coleotricha (Hochst.) G.B.	"	"	-	clay

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
C:				
Cadaba farinosa Forsk.	Capparidaceae	bush	censeni	sand;loam
Calotropis procera Ait.	Asclepiadaceae	"	bamammbi	sand;loam
Cardiospermum halicacabum L.	Cucurbitaceae	vine	-	loam
Carissa edulis Vahl.	Apocynaceae	tree	gumi nai	loam
Cassia Absus L.	Ceasalpiniodeae	annual forbe	oolo lawbé	clay;rocky
C. nigricans Vahl.	"	"	sinjajel	clay;ironstone
C. sie[illegible]ia D.C.	"	tree	cinanawi/cingooli	sand;loam
C. Tora L.	"	annual forbe	oolo	loam;clay
Celosia trigyna L.	Amaranthaceae	"	gurdal	sand
Cenchrus biflorus Roxb.	Graminae	annual grass	niakaberé	sand
Centaurea Perrottetii D.C.	Compositae	annual forbe	jon baali	loam;sand
Ceratotheca sesamoides Endl.	Pedalaceae	"	wulolel	ironstone
Cercestis Afzelii Schott.	Araceae	"	footo	clay;loam
Chloris pilosa Sch. & Thonn.	Graminae	annual grass	dankel colel	sand;clay
C. Prieurii Kunth.	"	"	-	sand;clay
Chrozophora plicata (Vahl.) A. Juss.	Euphorbiaceae	annual forbe	bamto	clay
C. senegalensis (Lam.) A. Juss.	"	"	puré	sand;clay
Cissus quadrangularis L.	Ampelidaceae	liana	endunyiba/potte gundo	loam;ironstone
Cleistopholis patens (Benth.) Engl. & D.	Annonaceae	tree	kukuwi	ironstone
Cleome viscosa L.	Capparidaceae	annual forbe	-	rocky
Colocynthis vulgaris Schrad.	Cucurbitaceae	vine	-	loam

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Combretum aculeatum Vent.	Combretaceae	tree	lawnaadi	sand;loam
C. geitonophyllum Diels.	"	"	dugornawi	loam;ironstone
C. glutinosum Perr.	"	"	dokki	loam;ironstone
C. Lecardii Engl. & diels.	"	"	bummi	ironstone
C. micranthum G. Donn.	"	"	talli	loam;ironstone
C. nigricans Lepr.	"	"	buski	loam;ironstone
C. niorense Aubr.	"	"	-	ironstone
Commelina Forskalaei Vahl.	Commelinaceae	annual forbe	walwalandé	sand;loam
Corchorus olitorius L.	Tiliaceae	annual forbe	jilé	clay
C. tridens L.	"	"	ladobali	clay;loam
Cordia Myxa L.	Borraginaceae	tree	camanowi	clay
C. sinensis Lam.	"	"	-	sand
Crinum pauciflorum Bak.	Amaryllaceae	bulbous forbe	ngaado	loam;clay
Crotalaria cylindrocarpa D.C.	Papilionoideae	annual forbe	jato	sand;clay
C. Perrottetii D.C.	"	"	niakaberé	sand;loam
C. retusa L.	"	"	-	clay
Ctenium elegans Kunth.	Graminae	annual grass	celal	sand
Cucumis melo L.	Cucurbitaceae	vine	denel wandu	loam
Cyperus difformis L.	Cyperaceae	annual sedge	-	clay
C. fenzelianus	"	"	-	clay
C. Iria L. "	"	"	hissel	clay
C. maculatus Bock.	"	"	ossel	sand;loam

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
D:				
Dactyloctenium aegyptium Beauv.	Graminae	annual grass	burgol colel	loam;clay
Dalbergia melanoxylon G. & Perr.	Papilionoideae	tree	jalambani	clay
Desmodium hirtum G. & Perr.	Papilionoideae	annual forbe	-	loam;clay
Dichrostachys glomerata (Forsk.) Chiov.	Mimosoideae	bush	burli	loam;clay
Dicliptera verticillata (Forsk.) C. Chr.	Acanthaceae	annual forbe	-	loam;clay
Digitaria argillacea (H. & Ch.) Fern.	Graminae	annual grass	-	loam;clay
D. gayana Stapf.	"	"	-	loam
D. horizontalis Willd.	"	"	mussa ladel	loam
D. longiflora Pers.	"	"	-	ironstone
D. velutina P. Beauv.	"	"	-	sand
Diheteropogon Hagerupii Hitch.	Graminae	annual grass	-	loam
Diospyros mespiliformis Hochst.	Ebenaceae	tree	dunubé	clay
Dipcadi longifolium Bak.	Liliaceae	bulbous forbe	ngaado	loam
Dolichos Daltoni Webb.	Papilionoideae	annual forbe	-	clay
Dopatrium senegalense Benth.	Scrofulariaceae	"	-	clay
E:				
Echinochloa colona Link.	Graminae	annual grass	ndiriri	clay
Eleusine indica Gaertn.	"	"	lumlumo	loam;clay
Elinorus elegans Kunth.	"	"	munmuto	loam;ironstone
Elytrophorus spicatus A. Cam.	Cyperaceae	annual sedge	-	clay
Entada africana G. & Perr.	Mimosoideae	tree	padapari	clay;loam

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Eragrostis cilianensis Lutati.	Graminae	annual grass	yalalo	clay
E. ciliaris R. Br.	"	"	ndiriri	clay
E. diplachnoides Steud.	"	"	raneré	clay;loam
E. lingulata W.D. Clayton.	"	"	-	sand
E. perbella K. Schum.	"	"	-	sand
E. pilosa P. Beauv.	"	"	-	sand
E. tremula Hochst.	"	"	-	sand
E. turgida DeWild.	"	"	-	clay
Eriospermum abyssinicum Bak.	Liliaceae	bulbous forbe	-	clay
Erythrina senegalensis D.C.	Papilionoideae	tree	mototay	clay
Euphorbia convolvuloides Hochst.	Euphorbiaceae	annual forbe	nofel mbalu	loam
E. polycnemoides Hochst.	"	"	-	clay
F:				
Feretia apondanthera Del.	Rubiaceae	liana	combi	loam;ironstone
Ficus platyphylla Del.	Moraceae	tree	dinndeewi	clay
Fimbristylis exilis Roem. & Sch.	Cyperaceae	annual sedge	eesil	loam
G:				
Gardenia erubescens Stapf.	Rubiaceae	tree	bosowi	loam;clay
G. ternifolia K. Schum.	"	"	dingali	loam;clay
Glinus lotoides L.	Molluginaceae	annual forbe	takonpuli	loam
G. oppositifolius (L.) Aug. DC.	"	"	-	clay
Grewia bicolor Juss.	Tiliaceae	bush	kelli	sand;loam

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Grewia flavescens Juss.	Tiliaceae	bush	kelli nahi	loam;ironstone
G. mollis Juss.	"	"	kelli niibi	clay
Guiera senegalensis J.F. Gmel.	Combretaceae	"	geloki	sand;loam
H:				
Hackelochloa granularis O. Kze.	Graminae	annual grass	-	loam;ironstone
Heeria insignis (Del.) O. Kze.	Anacardiaceae	tree	keeleeli	loam
Heliotropium bacciferum Forsk.	Borraginaceae	annual forbe	-	clay
H. strigosum Willd.	"	"	worowallé	sand;loam
Hexalobus monopetalus (A. Rich.) E. & D.	Annonaceae	tree	boili	clay
Hibiscus asper Hook.	Malvaceae	annual forbe	foleré	loam;clay
H. panduriformis Burm.	"	"	polli	clay
Hybanthus thesiiforlius (Juss.) H. & D.	Violaraceae	"	balewell	sand;clay
Hygrophila senegalensis (Nees.) T. And.	Acanthaceae	"	-	clay
I:				
Indigofera aspera Perr.	Papilionoideae	annual forbe	legi legiral	sand;loam
I. astragalina DC.	"	"	nornowel	sand;loam;clay
I. bracteolata DC.	"	"	-	loam
I. dendroides Jacq.	"	"	legi	sand;loam;clay
I. geminata Bak.	"	"	durman dayet	rocky
I. Leprieurii Bak.	"	"	leliko é badé	sand;loam
I. leptoclada Harms.	"	perenial forbe	-	loam;ironstone
I. macrocalyx G. & Perr.	"	annual forbe	-	loam;ironstone

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Indigofera pilosa Poir.	Papilionoideae	annual forbe	-	sand;loam
I. secundiflora Poir.	"	"	-	sand
I. trichopoda Lepr.	"	"	-	ironstone
Ipomaea acanthocarpa (Choisy.) A. & Sch.	Concolvulaceae	vine	-	clay
I. coscinosperma Hochst.	"	"	-	ironstone
I. pes-tigridis Linn.	"	"	-	sand;loam
I. pileata Roxb.	"	"	-	loam;clay
I. vagans Bak.	"	"	-	clay
I. verticillata Forsk.	"	"	-	loam;clay
J:				
Jacquemontia tamnifolia (L.) Griseb.	"	"	tirdé	loam;clay
Jussiaea erecta L.	Onagraceae	annual forbe	kumanbulo	sand;clay
Justicia kotschyi (Hochst.) Dandy.	Acanthaceae	"	-	loam
K:				
Khaya senegalensis (Desr.) A. Juss.	Meliaceae	tree	kahi	clay
Kohautia confusa (H. & Dalz.) Bren.	Rubiaceae	annual forbe	-	loam;clay
L:				
Lannea acida A. Rich.	Anacardiaceae	tree	belluki	loam
L. velutina A. Rich.	"	"	tuko nabé	loam
Leonotis africana (P. Beauv.) Briq.	Labiaceae	annual forbe	kumabulo	sand;clay
Lepidagathis anobrya Nees.	Acanthaceae	"	uggutel	loam;ironstone
Leptadenia hastata (Pers.) Decne.	Asclepiadaceae	vine	sapato	sand;loam

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Leptochloa caerulescens Steud.	Graminae	annual grass	-	clay
Loeseneriella africana (Willd.) R. Wil.	Celastraceae	tree	delbi	ironstone
Lonchocarpus laxiflorus G. & Perr.	Papilionoideae	tree	keleli	loam
Lotus arabicus L.	"	annual forbe	balamadié	clay
Loudetia hordeiformis Hubb.	Graminae	annual grass	celbel	sand;loam
L. togoensis Hubb.	"	"	yalalo/celbi	loam
M:				
Maerua angolensis DC.	Capparidaceae	tree	bagu	loam
M. oblongifolia (Forsk.) A. Rich.	"	annual forbe	lellello	loam
Maytenus senegalensis (Lam.) Exell.	Simaroubiaceae	tree	giyel gooti	loam
Melliniella micrantha Harms.	Papilionoideae	annual forbe	hudo bali	clay;ironstone
Melochia corchorifolia L.	Sterculiaceae	"	-	clay
Merremia aegyptiaca L. Urban.	Convolvulaceae	"	kopol	sand
M. pinnata (Hochst.) Hallier.	"	"	-	sand
Microchloa indica (L.) Beauv.	Graminae	annual grass	-	sand;loam
Mitracarpus scaber Zucc.	Rubiaceae	annual forbe	sholofel	clay
Mitragyna inermis (Willd.) O. Kze.	"	tree	koli	clay
Mollugo nudicaulis Lam.	Molluginaceae	annual forbe	hudo beeli	ironstone
Momordica Charantia L.	Cucurbitaceae	vine	-	sand
Monochria brevipetiolata Verde.	Pontederiaceae	annual forbe	-	clay
Mukia maderaspatana (Linn.) M.J. Roem.	Cucurbitaceae	vine	-	loam;clay

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
O:				
Oldenlandia merbacea (L.) Roxb.	Rubiaceae	annual forbe	-	loam;clay
Opilia celtidifolia (G. & Perr.) Endl.	Opiliaceae	tree	korum kohi	loam;clay
Ostryoderris Stuhlmannii (Taub.) Dunn.	Papilionoideae	tree	bani ndaneewi	loam
Oryza brachyantha A. Chev.	Graminae	annual grass	maro beeli	clay
O. sativa L."	"	maro	clay	
P:				
Pancratium trianthum Herb.	Amaryllaceae	bulbous forbe	-	sand;loam
Pandiaka Heudelotii (Moq.) Hook.	Amaranthaceae	annual forbe	-	loam;clay
Panicum Afzelli S.W.	Graminae	annual grass	padgiri jawré	clay;ironstone
P. anababtismum Steud.	"	"	dadie dajé	clay
P. laetum Kunth.	"	"	padgiri	sand;loam;clay
Paspalum scrobiculatum L.	"	"	njawri	loam;clay
Pennisetum pedicellatum Trin.	"	"	wulundé	loam;clay
Peristrophe bicalyculata (Retz.) Nees.	Acanthaceae	annual forbe	-	loam
Phaseolus scaberulus Miq.	Papilionoideae	"	tirdé	loam;clay
Phyllanthus Niruri L.	Euphorbiaceae	"	-	clay
P. pentandrtus Sch. & Th.	"	"	ceduwawa	sand;loam
Piliostigma reticulatum (DC.) Hochst.	Ceasalpinioideae	tree	barkeewi	sand
Polycarpaea linearifolia DC.	Carophyllaceae	annual forbe	delbi	sand;loam;ironstone
Polygala arenaria Willd.	Polygalaceae	"	-	clay
P. multiflora Poir.	"	"	legi legirgal	loam;clay

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Portulaca oleracea L.	Portulaceae	annual forbe	lalelé patiok	clay
Pterocarpus erinaceus Poir.	Papilionoideae	tree	bani balewi	loam;clay
P. lucens Lepr.	"	"	cegné	loam;ironstone
Pupalia lappacea (L.) Juss.	Amaranthaceae	annual forbe	-	sand
R:				
Rogeria adenophylla J. Gay	Pedalaceae	annual forbe	-	clay
S:				
Schizachyrium brevifolium Nees.	Graminae	annual grass	munmuto	clay
S. exile Stapf.	"	"	-	sand;rocky
S. nodulosum Stapf.	"	"	garlabal	loam;ironstone
S. urceolatum (Hack.) Stapf.	"	"	-	ironstone
Schoenefeldia gracilis Kunth.	"	"	cilbel	sand;clay
Scirpus praelongatus Poir.	Cyperaceae	annual sedge	-	clay
Sclerocarya birrea (A. Rich.) Hochst.	Anacardiaceae	tree	eeri	loam
Securidaca longipedonculata Fres.	Polygalaceae	"	allali	loam
Securinega virosa (R. & W.) Baill.	Euphorbiaceae	bush	cambel gorel	sand;loam
Sesbania plachycarpa DC.	Papilionoideae	annual forbe	-	loam
S. Sesban (L.) Merril.	"	tree	ganndol	sand;loam
Setaria pallidifusca Stapf. & Hubb.	Graminae	annual grass	lassel dawagdé	sand;loam
Sida rhombifolia L.	Malvaceae	annual forbe	-	sand;loam
S. schimperiame	"	"	-	sand

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
S. stipulata Cav.	Malvaceae	annual forbe	palpalel	loam;ironstone
Sphaeranthus senegalensis DC.	Compositae	"	morlu boda	clay
Sphenocloa zeylanica Gaertn.	Sphenoclaceae	"	-	clay
Sporobolus coromandelianus Kunth.	Graminae	annual grass	barawo	loam
S. festivus Hochst.	"	"	padgiri boderi	loam;rocky
Sterculia setigera Del.	Sterculiaceae	tree	bobori	loam
Stereospermum kunthianum Cham.	Bignonaceae	"	cinongawi	loam
Striga aspera (Willd.) Benth.	Scrofulariaceae	annual forbe	-	ironstone
Strophanthus sarmentosus DC.	Apocynaceae	liana	bonnji	loam
Strychnos spinosa Lam.	Loganaceae	tree	giyel gooti	ironstone
T:				
Tamarindus indica L.	Mimosoideae	"	cigirleewi/dami	loam;clay
Tephrosia bracteolata G. & Perr.	Papilionoideae	annual forbe	-	loam;clay
T. gracilipes G. & Perr.	"	"	kebel	ironstone;rocky
T. linearis (Willd.) Pers.	"	"	-	clay
T. pedicellata Bak.	"	"	-	loam;clay
T. platycarpa G. & Perr.	"	"	-	sand;clay
Terminalia macroptera G. & Perr.	Graminae	annual grass	-	clay
Tetrapogon spathaceus Hack.	Graminae	annual forbe	-	sand
Triumfetta pentandra A. Rich.	Tiliaceae	annual forbe	-	loam;clay
U:				
Urelytrum annum Stapf.	Graminae	annual grass	-	ironstone
Urena lobata L.	Malvaceae	annual forbe	-	ironstone

TABLE C1. (con't.)

Scientific Name & Authority	Family	Form	Name in Pulaar[b]	Soil type(s)
Urginea nigritana Bak.	Liliaceae	bulbous forbe	-	sand
U. Sebirei Berth.	"	"	-	sand
V:				
Vicoa leptoclada (Webb.) Dandy.	Compositae	annual forbe	ganndel	clay
Vigna ambacensis Bak.	Papilionoideae	"	-	loam
V. sinensis (L.) Savi.	"	"	niebé	loam;clay
W:				
Waltheria indica L.	Sterculiaceae	annual forbe	gurgutal	sand;clay
Wissadula amplissima (L.) Fries.	Malvaceae	"	-	ironstone
Z:				
Ziziphus mauritiana Lam.	Rhamnaceae	bush	jaabi	sand;loam
Z. mucronata Willd.	"	"	jaabi fowru	ironstone
Zornia glochidiata Reichb.	Papilionoideae	annual forbe	denndé/dengé	sand;loam

SOURCE: Survey data.

NOTES: [a]A complete set of herbarium samples has been left with the Project, and another complete set has been given to the Herbarium of Dr. K. Dieye at LNERV/Dakar.

[b]Transliteration "C" = ch, as in Charles; "j" = j, as in Jack; "ng" = gn, as in sign.

APPENDIX D.

RESULTS OF 1983/1984 FORAGE TRIALS

TABLE D1.

RESULTS OF 1983/1984 FORAGE TRIALS[a]

Species	Form	Source of Seeds[b]	1983 Performance[c]	1984 Performance[d]
1. Acacia albida	tree	Senegal/NAS	21% germination	no survival in plot
2. A. farnesiana	tree	Australia/NAS	3% germination	no survival in plot
3. A. linarioides	tree	Australia/NAS	3% germination	100% survival
4. A. macrostachya	bush	local	10% germination	100% survival
5. A. raddiana	tree	Senegal/NAS	3% germination	no survival in plot
6. A. Senegal	tree	Mauritania/DRIG	9% germination	10% survival
7. Aeschynomene americana	annual legume	ILCA #81125	-[e]	fair stand
8. A. falcata	annual legume	ILCA #77239	good stand and seed production	good stand, fair seed set
9. Alysicarpus glumaceus	annual legume	ILCA #77117	-	fair stand
10. A. vaginalis	perennial legume	ILCA #78068	-	poor stand
11. Atriplex canescens	bush	USA/NAS	no germination	no germination
12. A. nummularia	bush	Australia/NAS	no germination	no germination
13. Atylosia scaraboides	perennial legume	ILCA #77063	-	fair germination and stand
14. Bauhenia rufescens	bush	local	30% germination	no survival in degraded site
15. Boscia senegalensis	bush	local	no germination	-
16. Brachiaria distichophylla	annual grass	Mauritania/DRIG	good foliage and seed production	-
17. Cajanus cajan	perennial legume	Mauritania/DRIG	good stand, low herbage	no survival
18. Cassia rotundifolia	perennial legume	ILCA #77233	-	fair stand
19. Cenchrus ciliaris v. Bilebla	perennial grass	FAO #54.318	poor germination, good stand	100% survival; poor germination of new seeds
20. C. ciliaris v. Gayndah	perennial grass	FAO #54.319	very good germination and stand	100% survival; good germination of new seeds
C. ciliaris v. Gayndah	perennial grass	Australia/ILCA #6645 lot 4	-	poor germination in degraded site

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TABLE D1. (con't.)

Species	Form	Source of Seeds	1983 Performance	1984 Performance
21. C. ciliaris v. Molopo	perennial grass	ILCA #77032	poor germination, good stand, good regrowth in dry season	good survival; poor germination of new seeds
C. ciliaris v. Molopo	perennial grass	Australia/ILCA #7143 lot 3	-	poor germination when broadcast
22. C. ciliaris v. Nunbank	perennial grass	FAO #54.320	good germination, very good stand	100% survival; good germination of new seeds
C. ciliaris v. Nunbank	perennial grass	Australia/ILCA #6612 lot 3	-	poor germination when broadcast
23. C. ciliaris v. K.A.	perennial grass	FAO #55.887	-	fair germination but poor herbage in degraded site
24. C. ciliaris v. Palsana	perennial grass	ILCA #77289	fair germination, good stand	good survival; poor germination of new seeds
25. C. ciliaris v. USA	perennial grass	ILCA #79013	poor germination, poor stand	fair survival
26. Centrosema brazilianum	perennial legume	Equador/NAS	poor germination, fair stand, no seed production	no survival
C. brazilianum	perennial legume	ILCA #77088	-	poor germination and stand
27. Centrosema haïtiens	perennial legume	ILCA #77084	-	poor germination and stand
28. C. poscuorum	perennial legume	Brazil/NAS	poor germination, fair stand, no seed	no survival
C. poscuorum	perennial legume	ILCA #77060	-	poor germination and stand
29. C. pubescens	perennial legume	ILCA #82732	-	poor germination and stand
C. pubescens	perennial legume	ILCA #78050	-	poor germination and stand
30. C. pubescens v. Belalto	perennial legume	ILCA #77248	-	poor germination and stand
31. C. virginianum	perennial legume	ILCA #77249	-	poor germination and stand

TABLE D1. (con't.)

Species	Form	Source of Seeds	1983 Performance	1984 Performance
32. Clitoria ternatea	perennial legume	Australia/ILCA #80011	-	poor germination, poor stand
C. ternatea	perennial legume	Australia/ILCA #80012	-	poor germination, good stand
C. ternatea	perennial legume	Australia/ILCA #80013	-	poor germination, poor stand
C. ternatea	perennial legume	Australia/ILCA #80014	-	poor germination, poor stand
C. ternatea	perennial legume	ILCA #77085	-	poor germination, fair stand
33. Crotalaria anagyroïdes	perennial legume	ILCA #76002	-	fair germination, good stand
34. Desmodium distortum	perennial legume	ILCA #79081	-	fair germination, fair stand
35. D. intortum v. Greenleaf	perennial legume	FAO #59.274	-	poor germination, very poor stand, no seed set
36. D. uncinatum v. Silverleaf	perennial legume	FAO #59.275	-	poor germination, very poor stand, no seed set
37. Dolichos lablab	perennial legume	Mauritania/DRIG	good germination, fair stand	no survival
38. Echinochloa stagnina	perennial grass	Mali/ILCA #81122	no germination in plot nor in waterlogged area	-
39. Entada africana	tree	local	10% germination	poor survival
40. Erogrostis lehmaniana	annual grass	USA/DRIG	no germination	-
41. Eucalyptus camaldulensis	tree	Australia/NAS	very low germination	poor survival
42. Geoffroea decorticans	bush	Chile/NAS	no germination	-
43. Glycine Wightii	perennial soybean	ILCA #79067	-	poor germination, no survival
44. G. Wightii v. Cooper	perennial soybean	ILCA #77221	-	poor germination, no survival
45. Grewia bicolor	bush	local	10% germination	good survival
46. Leucaena leucocephala	tree	Mexico/NAS	13% germination	no survival
L. leucocephala	tree	Mauritania/DRIG	4% germination	4% survival
L. leucocephala	tree	Senegal/ISRA	3% germination	5% survival, poor vigor

TABLE D1. (con't.)

Species	Form	Source of Seeds	1983 Performance	1984 Performance
47. Macroptilium atropurpureum	perennial legume	Mexico/NAS	fair germination, good stand and seed	no survival
M. atropurpureum	perennial legume	ILCA #82797	-	good germination, good stand and seed set
48. M. bracteatum	perennial legume	ILCA #77247	-	good germination, good stand and seed set
49. M. lathyroides	perennial legume	ILCA #66005 & 77007	-	good germination, good stand and seed set
50. Macrotyloma axillare v. Archer	perennial legume	ILCA #77242	-	poor germination and stand
51. Medicago sativa	perennial legume	SW-USA	very poor germination and stand, no seed set	no survival
52. Panicum antidotale	perennial grass	ILCA #77291	poor germination and poor stand	no survival; poor germination of new seeds
53. Panicum maximum	perennial grass	FAO #57.748	no germination	-
54. P. maximum v. Trigloglume	perennial grass	FAO # 46.536	poor germination and poor stand	no survival; no germination of new seeds
55. P. maximum v. Gatton	perennial grass	ILCA #77272	no germination	-
56. P. maximum v. K-187	perennial grass	ILCA #77000	no germination	-
57. Panicum maximum v. 89	perennial grass	ILCA #77001	no germination	-
58. P. maximum v. G23	perennial grass	ILCA #77002	no germination	-
59. P. maximum v. Hamil	perennial grass	ILCA #77267	no germination	-
60. P. sonorum	annual grass	USA/NAS	fair germiantion, good stand and seed set	-

TABLE D1. (con't.)

Species	Form	Source of Seeds	1983 Performance	1984 Performance
61. Parkinsonia aculeata	tree	Mauritania/DRIG	8% germination, poor survival in degraded site	no s ival in degraded site
P. aculeata	tree	Senegal/NAS	no germination	-
62. Pennisetum purpureum v. Kizozi	perennial grass	ILCA #77127	no germination	no germination
63. P. purpureum v. Hybrid	perennial grass	ILCA #81126	no germination	no germination
64. P. typhoides v. Souna	annual millet	ILCA #81117	good germination and very good seed set but subject to black smut	-
65. P. typhoides v. Sanio	annual millet	ILCA #81118	good germination, good herbage but low seed set, subject to bird and insect attack	-
66. Phaseolus acutifolius	perennial legume	USA/NAS	good germination and seed set	no survival
67. Piliostigma reticulatum	tree	local	10% germination	no survival
68. Prosopis alba	tree	Argentina/NAS	10% germination	100% survival
69. P. juliflora	tree	Senegal/NAS	5% germination	100% survival
70. Pterocarpus lucens	tree	local	no germination	-
71. Sesbania Sesban	tree	local	10% germination	poor survival
72. Simmondsis chinensis	bush	USA/NAS	no germination	no germination
73. Stylosanthes fruticosa	perennial legume	ILCA #77064	-	fair germination, good stand
74. S. hamata	perennial legume	Brazil/NAS	no germination	-
75. Stylosanthes hamata v. Verano	perennial legume	FAO #55.889	-	poor germination and stand
S. hamata v. Verano	perennial legume	ILCA #77013	-	fair germination and stand
76. S. humilis	perennial legume	ILCA #77017	-	fair germination and good stand
77. S. humilis v. Lawson	perennial legume	ILCA #77066	-	fair germination and good stand
78. S. humilis v. Townsville	perennial legume	FAO #59.273	-	poor germination and stand
S. humilis v. Townsville	perennial legume	ILCA #77305	-	good germination and stand

TABLE D1. (con't.)

Species	Form	Source of Seeds	1983 Performance	1984 Performance
79. S. Guianensis	perennial legume	ILCA #66006	-	poor germination and stand
80. S. Guianensis v. Cook	perennial legume	FAO #51.752	-	no germination
81. S. Guianensis v. Schofield	perennial legume	FAO #51.751	-	no germination
82. S. scabra	perennial legume	Coastal S. America/NAS	no germination	-
83. S. scabra	perennial legume	ILCA #77068	-	poor germination and stand
84. S. subscricea	perennial legume	ILCA #77076	-	good germination and stand
85. Tamarindus indica	tree	local	30% germination	poor survival
86. Tarconanthus comphoratus	bush	South Africa/NAS	no germination	-
87. Tylosema esculentum	perennial legume	Kalahari Desert/NAS	no germination	-
88. Vigna unguiculata	annual legume	Senegal/ISRA	fair germination and seed set, very good germination, stand and seed set in sorghum field	-
89. Ziziphus mauritiana	bush	local	10% germination	good survival

SOURCE: Survey data.

NOTES: [a]All trails were in fenced plots unless noted otherwise.

[b]NAS = National Academy of Sciences, Board on Science and Technology; DRIG = Projet de Developpement Rural Integré de Guidimaka, Islamic Republic of Mauritania; ILCA = International Livestock Center for Africa; FAO = Food and Agriculture Organization of the United Nations; ISRA = Institut Senegalaise de Recherches Agricole; local = collected in Project Area;

[c]Total rainfall in 1983 was 475 mm.

[d]Total rainfall in 1984 was 350 mm.

[e]"-" indicates not tested.

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APPENDIX E.

PASTORAL UNIT PROPOSED BOUNDARY

TABLE E1.

SUMMARY OF PASTURES AND WATER-POINTS ASSIGNED TO PASTORAL UNITS IN THE PRELIMINARY DESIGN OF 1984

Pastoral Unit No.	Villages	Pastures[a]	Water-Points[b]
1	Mbaniou Sowol Ndiakone Gonadé	Lappol jummi, Boungal, Petel nalla, Cenel, Parawol capalli, Celli, Parawol Mbaniou, Lappol sambaduru, Furnange Ndiakone, Sanko, Sukaneré Total surface area = 23,310 ha	16, 22, Fété Kora Fété Gelluki
2	Diaré Mbolo Diaré Maboubé Medina Guiraye Garalla	Lappol cowlé oli, Garsi, Lappol danawol, Parawol jawol, Sintiou hamajindé, Walisabo, Parawol gaycali, Lapol belal, Kajel bopi, Parawol wafo, Sirkum, Louré baba ali, Kolimudu Total surface area = 20,630 ha	25, 15, 19, L5, Weendu Caba, Weendu Giwol, Weendu Gelongal, Kolimudu
3	Ndiya Toulekeedi Velingara Boulel	Bangé gawdé, Kessol Amadou Sy, Parawol jajié oli, Dunubil, Petel nyari, Adabé, Parawol bafo, Joudé Samba Sire, Lombolabi, Lappol furdu, Lappol bingal, Facojé, Lappol guotoki, Bowdi coyé, Bannu, Cilowaji, Bowol, Jawondu, Dugajé, Lappol belombé, Pilpilodé, Bogel gogor, Seno boboré, Koli, Lugeré janal, Furnangé Boulel, Yumuki, Petel sileymani, Mbaba, Row Boulel Total surface area = 32,750 ha	11, 2, 6, 10, Dudi, Fété Bowol, Fété Buni, Koli,
4	Youpé Amady Seno Youpé Sako Diamwelli Seouji Gourel Pathé Mbaye Girbandao	Waldewa, Sintiou demba, Nyarowal, Waalondo badi, Longeré ferlere, Barsafa, Arifundé	Weendu Almami, Weendu Longeré, Weendu Lingerou Weendu Seunde
	Diabougou Mossi Banipelli Youpé Pate	Total surface area = 12,585 ha	

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TABLE E1. (con't.)

5	Béllé Gourel Ablaye Diaw Boubouya Sintiou Sory Lamine Gourel Mama Sira Gourel Mamadou Bara	Bogal cala, Siiwde Béllé, Nyara, Jala, Merningel, Yorobi, Jamheri, Joupané, Muki jammi, Soya, Total surface area = 7,540 ha	Weendu Seega, Jela, Weendu Siiwé
6	Sintiou Fissa Arigabo Kundel Fissa Daro Seno Issaga Gourel Demba Konko Gourel Boulli Gourel Samba Koulibali	Gelongal, Galle almami, Sukeyurnaki, Kataval Fissa, Yaalofé, Kataval pauté cadé, Raflumbu, Boulebané, Yolihofa, Nyarowal sukké, Nyarowal kolinaji, Lugungol, Nyarcata, Jalombi, Kajel lewel, Bangé Sintiou Fissa Total surface area = 20,760 ha	L3, L4, L6, Weendu Heru
7	Wouboul Guirobe Sintiou Dicye Mamandao Niedebel (Kidira)	Cina, Bangé Falamé, Sambanjai, Barka, Kugel joy, Sammbo, Kaayé koli, Mama ginta, Mooro, Kerdellé, Kaski, Bumungal, Velingara, Hora, Falo sammbe idi, Fallo male-baydi,Huli hoota, Nyarowal Niédebel, Cagadé, Debé todderé, Bodowol, Kayé goumpeni, Hayré fowri, Hauré faldé, kataval Kidira, Row-hirnangé Diabougou Total surface area - 21,520 ha	Falamé
8	Oursoulé Seno Wandalé Walidiala Birfal Fete Golombi Gourel Mama Ndiya	Alibesel, Dangdé, Row Oursoulé, Sehingo, Lesdieo, Gambidiré, Furnangé Seno Wandalé, Caba, Cokké, Samba diego Total surface area = 17,470 ha	L1, L2, 12
9	Gabou Sarré Kadiel Samba Kontayé Seno Malik Ali	Guman amadou, Row Sarré, Nyarowal Kadiel, Ouroububu, Amaji sira, Karenabé Kadiel, Bangé Seno Malik Ali, Karenabé, Somsom, Masina, Badiara, Kooba, Gaboundamdé, kataval Samba Kontayé, Diambaké, Pallol Total surface area = 24,960 ha	Weendu Gabou,

TABLE E1. (con't.)

10	Sira Bocar Kane Sira Sissibe Sira Kalidu Sira Samba Gada Sira Simbin Lombol Tobito Gourel Gouibé	Namardi, Balki, Seeno, Dubbel, Laddé, Total surface area = 10,460 ha	Mangam, Wournbéré, Aluki, 7,
11	Bema Moribougou Alahina Bordé Diabal (Gounia)	Seno Bakel (Southern portion), Kollangal (Southern portion), Nyarowal Gounia, Dagomory, Arilelo, Amadou boutadé, Kataval Diabal, Nyarowal binné, Nyarowal bordé, Mbaraldou Total surface area = 17,245 ha	Mbaraldou, Kollangal
12	Sintiou Medina Medina Abdul Kadiel Seudu Lombol Ganji	Seno lalowi, Haeré dabo, Mbarallu, Nyarowal yéjé, Nyarowal Medina, Total surface area = 4,620 ha	Seane[c]Kadiel, Seane Ganji
13	Sintiou Seydou Doro Gourel Alassane Sintiou Thiengolel Gourel Samba Dioburu Sira Baidy Galle Amadi Dieri Gourel Dialoubé	Bagiri, Cengol lewol, Jaralongil, Dewniew, Koli, Ndunubi lawol, Ngaskanyarowal, Yeo, Nagana, Nyarowal Alassane, Dowheru, Ngabou, Nyarowal Dialoubé Total surface area = 9,790 ha	1
14	Ololdou Kahé Alaleri Mail Amath Mail Filly	Row Ololdou, Bangé Mail, Diegoulané, Laolwali, Hirnangé Kahé, Girnangi, Total surface area = 6, 090 ha	Seane Ololdou, Seane Alaleri

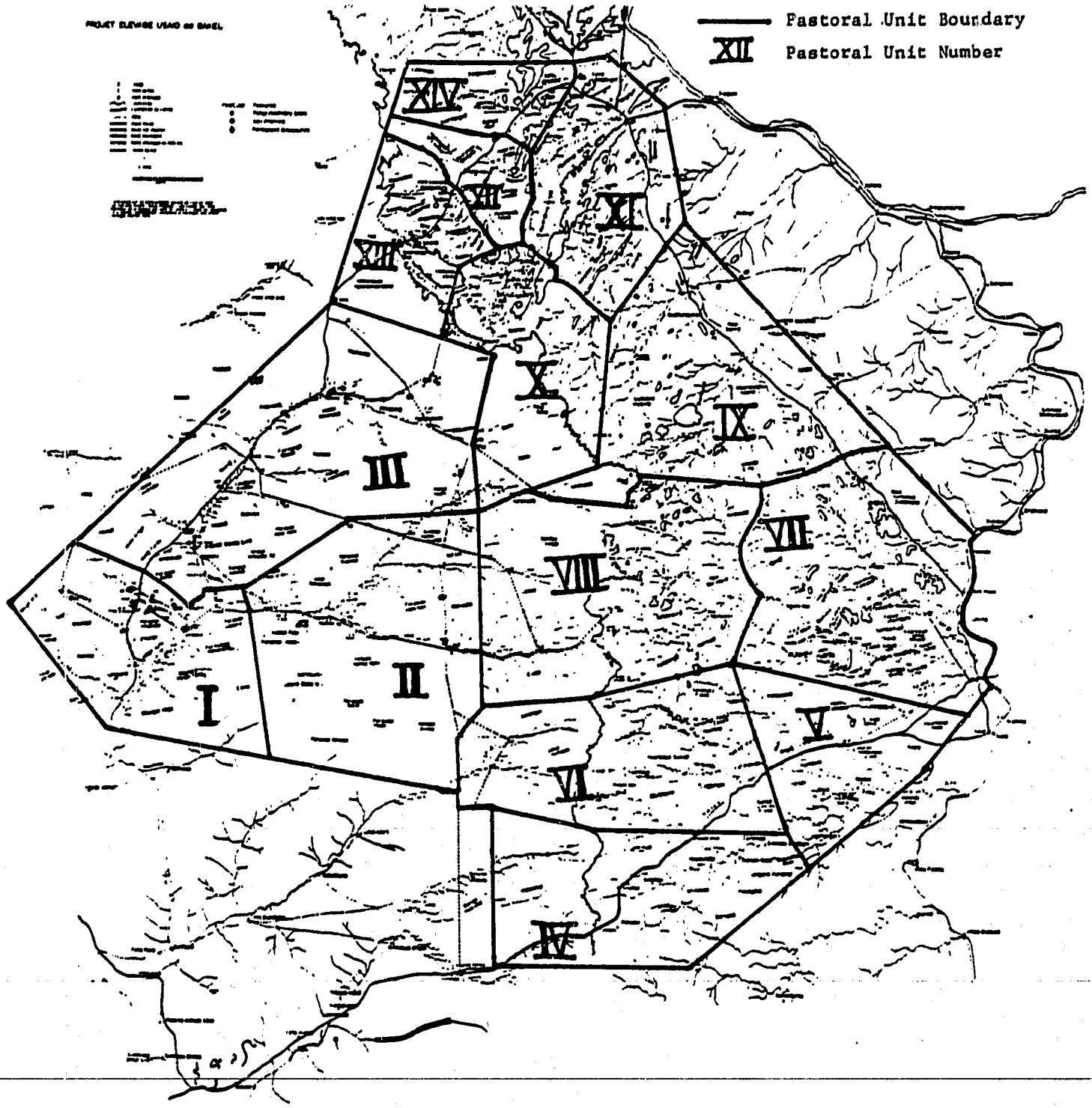
SOURCE: Survey data.

NOTES: [a]Each UP theoretically has exclusive use of the pastures and water points assigned to it. However, if necessary, the other pastures can be used if it is regulated through a system of "permits".

[b]The numbers refer to the numbers assigned to the artificial ponds.

[c]Ceane = hand-dug shallow wells in a streambed.

MAP E1. Map of Boundaries of Pastoral Units



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APPENDIX F.

MAPS

MAP F1. BASE MAP

(See pocket in back cover)

MAP F2. COLOR SOIL/VEGETATION MAP AND LEGEND

APPENDIX E2.

LEGEND FOR SOIL/VEGETATION CLASSIFICATION MAP

Color	Range Type Type de Paturage	Main Vegetation (Principaux Types de Vegetation)	Dominant Herb. (Herbacées Dominantes)	Dominant Woody Plants (Arbustes Dominantes)	Main Soil Types (Principaux Types de Sol)
	Ironstone Plateaux Plateaux ferrugineux	Wooded grassland Formation herbeuse-boisée	Guiera senegalensis Combretum glutinosum Acacia macrostachya Grewis bicolor Combretum nigricans	Diheteropogon Hagerupii Andropogon pseudapricus Elinorus elegans Pandiaka Heudelotii Borreria radiata	Gravelly sandy loam on ironstone Gravillonnaire et sablo-limoneux sur cuirasse ferrugineuse
	Floodplain (Gambia Basin) Versant (Bassin du Gambie)	Wooded grassland Formation herbeuse-boisée	Combretum glutinosum Guiera senegalensis Pterocarpus lucens Grewis bicolor Sterculia setigera	Loudetia togoensis Aeschynomene Schimperi Borreria radiata Diheteropogon Hagerupii Andropogon pseudapricus	Sandy loam on sandy clay loam sablo-limoneu sur argilo-limoneux
	Floodplain (Senegal Basin) Versant (Bassin du Senegal)	Wooded grassland Formation herbeuse-boisée	Acacia Seyal Feretia apondanthera Combretum micranthum Combretum glutinosum Balanites aegyptiaca	Andropogon pseudapricus Schoenefeldia gracilis Diheteropogon Hagerupii Aeschynomene Schimperi Borreria radiata	Sandy loam on clay loam sablo-limoneu sur argilo-limoneux
	Degraded (Gambia Basin) Degradé (Bassin du Gambie)	Degraded grassland Formation herbeuse degradée	Grewia bicolor Guiera senegalensis Boscia senegalensis Pterocarpus lucens Adenium obesum	Zornia glochidiata Microchloa indica Dactyloctenium aegyptium Eragrostis lingulata Schoenefeldia gracilis	Sandy loam on loam sablo-limoneu sur limon
	Degraded (Senegal Basin) Degradé (Bassin du Senegal)	Degraded grassland Formation herbeuse degradée	Balanites aegyptiaca Guiera senegalensis Acacia Senegal Acacia Seyal Ziziphus mauritiana	Microchloa indica Sporobolus festivus Cassia Tora Sida stipulata Zornia glochidiata	Sandy loam on clay loam sablo-limoneux sur argilo-limoneux

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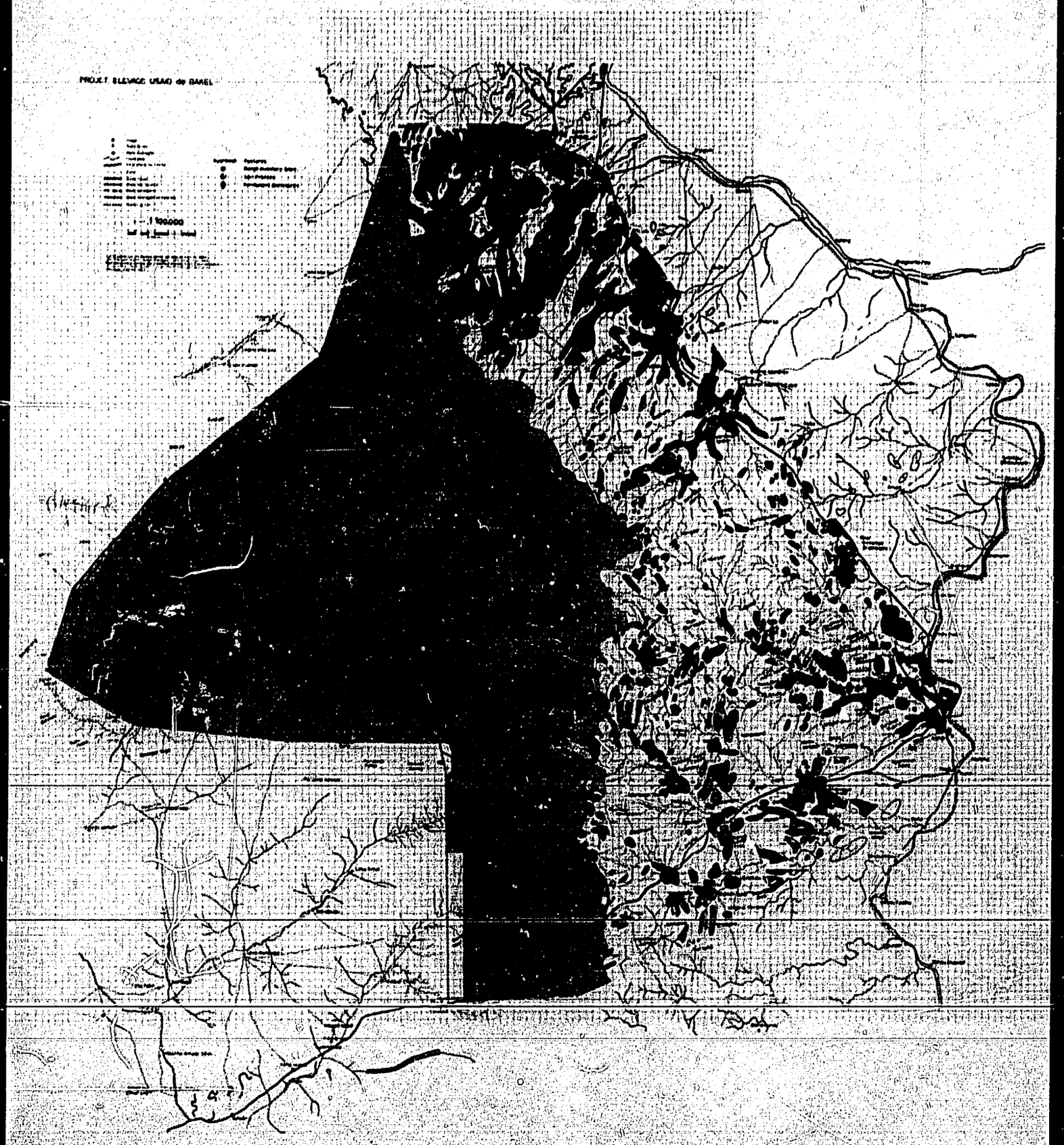
Color	Range Type Type de Paturage	Main Vegetation (Principaux Types de Vegetation)	Dominant Herb. (Herbacées Dominantes)	Dominant Woody Plants (Arbustes Dominantes)	Main Soil Types (Principaux Types de Sol)
	Hill Colline	Wooded bushland on hill & rocky outcrop Formation boisée-buissonnante sur collines et reliefs residuels	Acacia macrostachya Combretum glutinosum Combretum nigricans Combretum geitonophyllum Combretum micranthum	Panicum laetum Pandiaka Heudelotii Schizachyrium nodulosum Andropogon Chevalieri Cleome viscosa	stony sandy loam on bedrock gravillonnaire et sablo-limoneux sur quartz
	Foothill Pied de la colline	Wooded grassland Formation herbeuse-boisée	Combretum glutinosum Guiera senegalensis Lannea acida Grewia bicolor Sterculia setigera	Schoenefeldia gracilis Zornia glochidiata Aristida adscensionis Sporobolus festivus Dectyloctenium aegyptium	loamy sand on sandy clay loam limo-sablonneu sur sablo-argilo-limoneux
	Streambed (Gambia Basin) Cours d'eau (Bassin du Gambie)	Riparian Riverain	Combretum glutinosum Sclerocarya birrea Pterocarpus erinaceus Combretum micranthum Combretum nigricans	Pennisetum pedicellatum Bacopa hamiltoniana Borreria radiata Borreria stachydea Panicum laetum	sandy loam on silt loam sablo-limoneux sur limon
	Streambed (Senegal Basin) Marigot (Bassin du Senegal)	Riparian Riverain	Piliostigma reticulatum Acacia nilotica	null	sandy loam sablo-limoneux
	Open water Mare naturelle	Herbaceous fresh-water aquatic swamp Formation herbeuse-aquatique	null	Aeschynomene tambacoundensis Hygrophila senegalensis Oryza brachyantha Cyperus Iria	clay argile
	Swamp Marécage	Edaphic grassland and scattered tree mozaic Formation herbeuse-aquatique et mosaique boisée	Combretum glutinosum Combretum nigricans Guiera senegalensis Grewia bicolor Acacia macrostachya	Loudetia togoensis Andropogon pseudapricus Microchloa indica Diheteropogon Hagerupii Heliotropium strigosum	clay loam on ironstone argilo-limoneux sur cuirasse ferrugineuse
	Cultivated & fallow land Culture et jachère	Anthropic shrubland Formation anthropique	Combretum glutinosum Guiera senegalensis	Pennisetum pedicellatum Cassia Tora	sandy loam on sandy clay loam sablo-limoneux sur sablo-argilo-limoneux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Eastern Senegal Range and Livestock Development Project

Soils and Water Engineering

Allen Clark

Prepared by
Center for Research on Economic Development
University of Michigan

for
U.S. Agency for International Development (USAID)

Contract No. 685-0202-C-00-2137-00

February 1985

III

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EASTERN SENEGAL RANGE AND LIVESTOCK DEVELOPMENT PROJECT

SOILS AND WATER ENGINEERING

by

Allen Clark
Project Engineer

Prepared by
Center for Research on Economic Development
University of Michigan

for

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February 1985

INTRODUCTION

The construction of 18 pit-type livestock watering ponds has been a primary component of the USAID-financed Eastern Senegal Range and Livestock Project located in eastern Senegal. The purpose of the ponds is to provide water in areas with good rangeland that were previously underutilized during the dry season (October through May). These ponds also tend to reduce the grazing pressure around the local villages where wells, 40 meters in depth, provide a year-round water supply.

This report is a summary of a hydrologic study of the ponds carried out from June 1983 through May 1984 as a portion of an overall project evaluation. The ponds consist of excavated pits in ephermeral stream channels. The pits are approximately five meters deep and have a capacity of 3500 to 8000 cubic meters. Data were collected on rainfall, storm runoff volumes, livestock usage, pond water levels and sedimentation rates. The most striking conclusion from the study is that infiltration losses account for 70 to 90 percent of the water that is collected in each pond. This has serious consequences on their utility considering that the pond designs assumed losses, due to a combination of infiltration and evaporation, at 35 percent. Unfortunately mitigation of this problem is probably cost-prohibitive.

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1. DESCRIPTION OF RESEARCH AND RESULTS

1.1. POND DESIGN

Seventeen ponds were included in this study. The ponds are of two different designs, old and new, as shown in Figure 1.1. The principal difference is that the spoils pile is placed downstream of the old ponds and functions as a dam as opposed to the new ponds which have the waste piles on the sides so the maximum pond water level coincides with the downstream edge of the hole. The pond locations are shown on a map of the area in Figure 1.2. New ponds are designated by the letter "L" because they were constructed by Jean Lefebvre Inc.

1.2. WATERSHED CHARACTERISTICS

Each of the pond watersheds is outlined on a 1:200,000 map in Appendix A. The slopes of the watersheds are very small, usually less than 0.1 percent along the main stream channel, which reflects the fact that the entire area is a plateau. There are frequent, usually small, natural basins that collect runoff which typically dry several weeks after the final rainfall event.

The vegetation in the area is savannah, relatively thick for the Sahel. Small trees (acacia) and shrubs (combretum glutinosum) are typically spaced several meters apart. Larger trees such as baobabs and false baobabs (sterculia setigera) are located at much less frequent intervals. Grasses are mostly annuals with perennials occasionally found in the stream channels. The density of grass is difficult to characterize because each year large fires burn through portions of the area leaving the trees and shrubs but frequently destroying the grass. Thus, at the beginning of the rainy season, which lasts from June through September, there may be little grass, but after the first rains, new grass germinates and increases in size and numbers for the remainder of the wet months.

The plateau is typically underlain by a layer of ironstone which outcrops at a 10 to 20 meter drop-off (escarpment) defining the eastern edge of the plateau. The ironstone is typically shallow within several kilometers of the escarpment and in areas distant from the larger stream channels. It exists at a much deeper depth, if at all, in the areas of large ephemeral stream channels. Where the ironstone is shallow (20cm - 30cm) the overlying soil usually consists of gravelly sandy loam, the gravel being ironstone fragments. In the vicinity of the larger drainage channels the surface soil consists of a sandy loam underlain by sandy clay loam.

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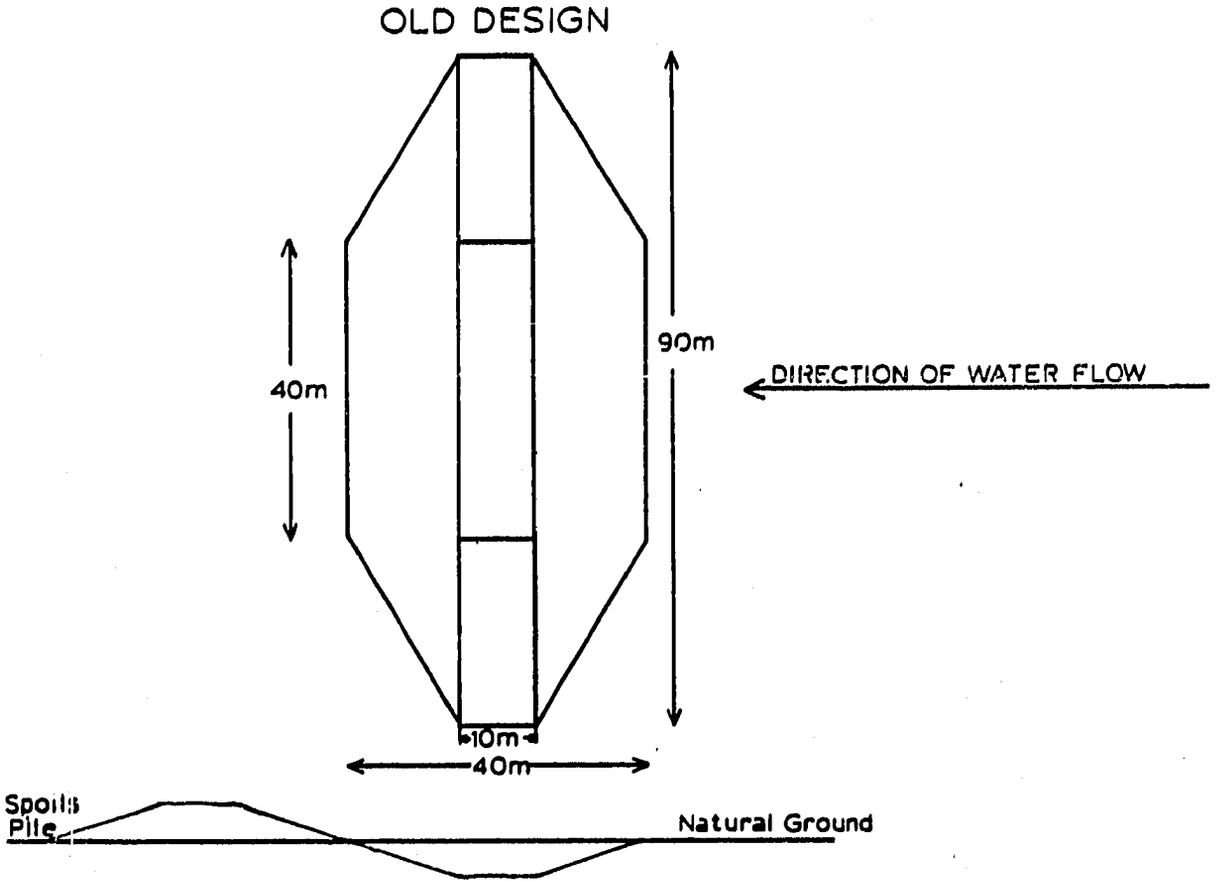
Figure 1.1. Old and New Pond Designs



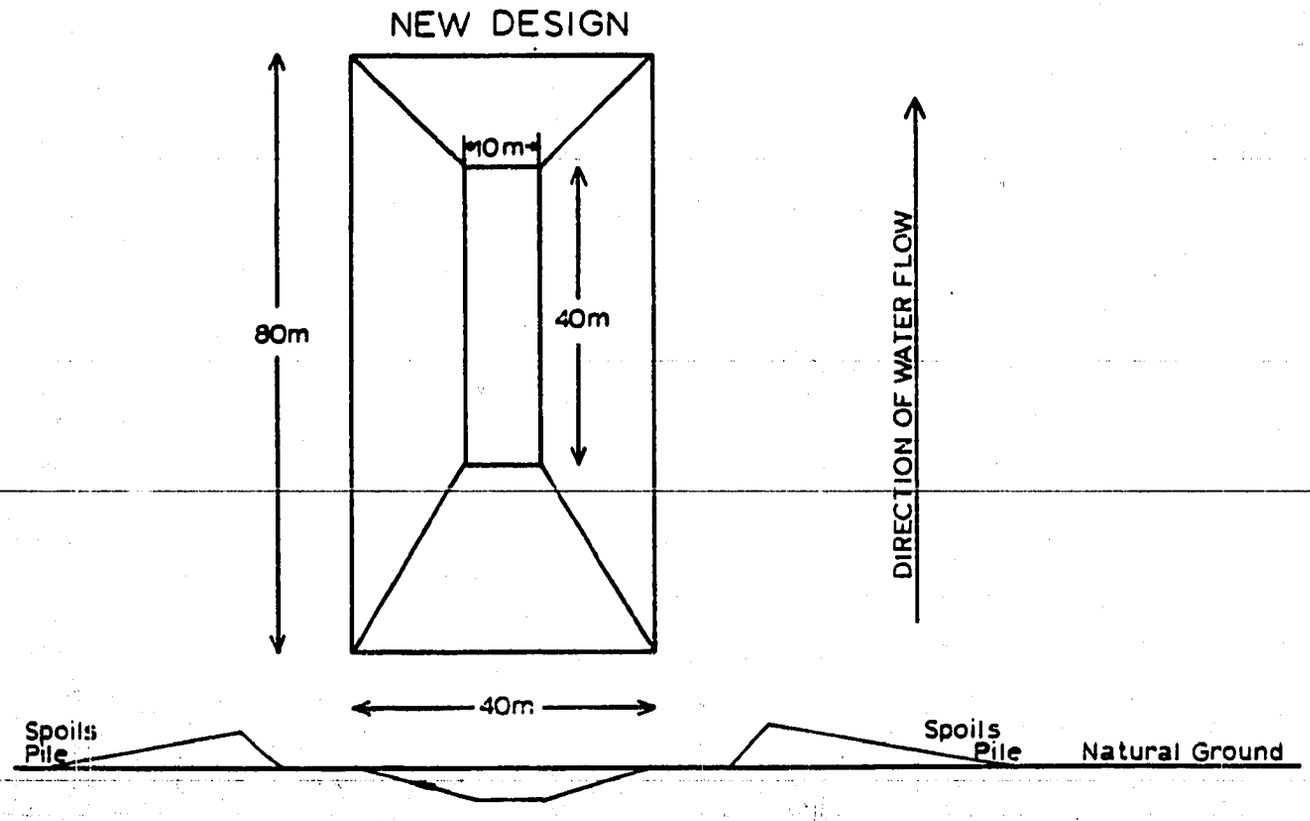
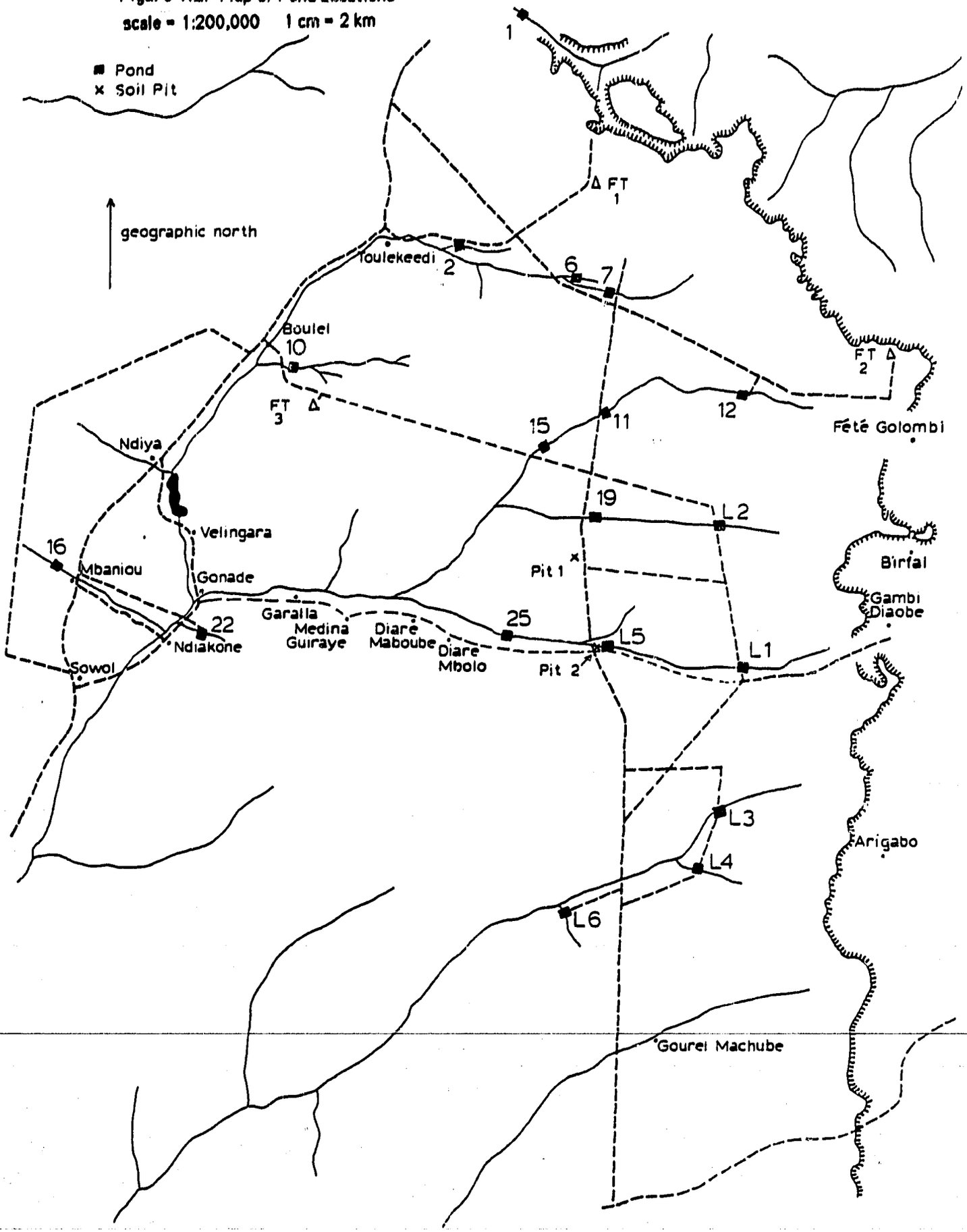


Figure 1.2. Map of Pond Locations
scale = 1:200,000 1 cm = 2 km



For the purposes of this study the soil shallowly underlain by ironstone is referred to as Type 1 and that found in the vicinity of large stream channels is designated as Type 2. Pits were excavated in each of the two soils and descriptions are included in Appendix B. It was observed that many more surface puddles resulted from rainfall on the finer drainage basin soils (Type 2) than on the coarser soils (Type 1). This indicates that runoff would be greater on Type 2 soil than on Type 1.

A summary of characteristics for each watershed is included in Table 1.1., giving the watershed areas, approximate proportions of the two soil types, and brief descriptions of the main stream channels.

1.3. RAINFALL

The rainfall map of Senegal indicates that the study area receives an average annual rainfall of between 500 and 600mm. This precipitation occurs in either high intensity thundershowers or steady rains over longer periods. Precipitation was monitored in the region with a network of rain gauges. These data appear in Appendix C. The rainfall record is not complete for any single gauge but it is estimated that the average over the area was approximately 475mm for the year. Each rainfall tended to be highly variable over the area as indicated by the rainfall of June 17th which is noted in Appendix C (Figure C2). The largest rainfall occurred on July 9th, apparently dropping over 100mm of rain in the eastern portions of the zone. Unfortunately the rain gauges were not read until 5 days after the event resulting in evaporation losses which distorted the measurements.

1.4. EVAPORATION

Estimations of potential evaporation were obtained from a study done in the Bakel area by a consulting firm, Land Systems, which is based in Italy. These data are estimates made by extrapolating data from Matam, Senegal. They are presented in Table 1.2.

1.5. POND WATER MEASUREMENT

A surveying level was used to measure pond water levels from the beginning of the rainy season (June) until they dried up (December through March). An effort was made to record pond levels as soon as possible after each rain, however poor road conditions caused delays at times, especially for the more remote ponds. Few data points were

TABLE I.1.

CHARACTERISTICS OF POND WATERSHEDS

Pond No.	Drainage Area (Km^2)	Soil Type	Stream Channel Remarks
1	5	Type 1 Dominant	Watershed sides exceed 1% slope into main channel
6	6	Type 1 Dominant	Main channel poorly defined
7	4	Type 1 Dominant	Main channel poorly defined
10	14	Equal areas each type	Well-defined channel
11	57	Equal areas each type	Large well-defined channel
12	35	Equal areas each type	Large well-defined channel
15	31	Equal areas each type	Large well-defined channel
16	8.4	Somewhat more Type 1 than Type 2	Three channels connect into large channel
19	21	Equal areas each type	Large well-defined channels
22	7	Equal areas each type	Large well-defined channels
25	90	Equal areas each type	Large well-defined channels
L1	24	Type 2 Dominant	Large well-defined channels
L2	10	Type 1 Dominant	Small channel
L3	16	All Type 1	Small channel
L4	18	Type 1 Dominant	Large well-defined channel
L5	70	Equal areas each type	Large well-defined channel
L6	3	Type 1 Dominant	Steep channel last 500 meters (3% slope)

TABLE 1.2.

ESTIMATED MONTHLY POTENTIAL EVAPORATION
IN THE BAKEL AREA

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
mm	143	148	180	200	210	179	160	144	132	139	138	131	1,904

collected for Pond 1 because of its distance from the home base in Mbaniou. After the ponds dried, each was surveyed to determine the appropriate volume to depth relationship. This information along with the water level data, yielded volume versus day of year curves which are presented in Appendix D. The method used for determining the water level versus volume relationship for each pond is discussed further in Appendix E. Some lines are extrapolated in the graphs. These are cases where ponds had not been measured just before or after a rainfall event. In these cases the pond was assumed to continue to decrease in volume at the same rate that it demonstrated for similar water levels earlier or later in the season. Extrapolations are shown as dashed lines on the volume curves. Pond depths are indicated on the right hand side of the graphs.

1.6. LIVESTOCK WATER CONSUMPTION

Estimates were made of livestock water consumption for four ponds. At Ponds 1, 10 and 16 an observer counted the number of animals that drank during a three-day period every two weeks. These data are assumed to be representative for the two-week period and were multiplied by assumed daily livestock consumption rates for different portions of the year to yield approximations of the total consumption from the three ponds.[1] For Pond 15 the number of livestock present on a daily basis was assumed from knowledge that the villages of Diare Mabobe and Diare M'Bolo kept most of their cattle at the pond from August 19 to October 31. The number of cattle was taken from 1981 census figures. This estimate for water consumption is likely to be high because some of the animals camped at Pond 15, drank at other ponds during the course of foraging. The estimates for each of the four ponds are given in Table 1.3. as well as the assumed values for individual animal consumption.

[1]This work was done by Maryam Niamir, Project Range Management Specialist.

TABLE 1.3.

LIVESTOCK WATER CONSUMPTION ESTIMATES
(liters)

Pond No.	Rainy Season 1 June-15 Sept.	Camp Season 15 Sept.-15 Oct.	Dry Season Variable Length	Total (M^3)
2	104,630	62,161	550,091 (45 days)	717
10	48,510	27,202	132,597 (30 days)	208
16	49,225	28,563	2,026,485 (135 days)	2154
15	(unknown)	320,400	801,000 (15 days)	1121

ASSUMED INDIVIDUAL ANIMAL CONSUMPTION RATES (liter/day)

	Rainy Season	Camp Season	Dry Season
Cattle	6	12	30
Goat/Sheep	2.5	3	5

1.7. SEDIMENTATION

Recent sediment accumulation was excavated from the bottom of eight ponds in order to determine the rate of accumulation. Pond depths were measured before and after cleaning and together with topographical surveys of the pits, were used to estimate the volume of sediment excavated from each pond. These data are presented in Table 1.4.

TABLE 1.4.

POND SEDIMENTATION ESTIMATES

Pond No.	Depth (M) Sediment	Volume (M^3) Sediment	Years of Accumulation	Volume (M^3) per year	Watershed (Km^2)
1	1.2	720	3	240	5
10	0.9	727	4	181	14
11	0.4	288	2	144	57
12	1.3	910	5	182	35
15	1.2	1132	4	283	31
19	1.5	1840	3	613	21
22	1.3	910	2	455	7
25	1.0	600	4	150	90

2. ANALYSIS AND CONCLUSIONS

2.1. POND WATER VOLUMES

All the ponds filled at least once during the season. The most striking feature exhibited by the volume versus time curves (see Appendix D) is the sharp decrease in water volume when the ponds are reasonably full. This can only be explained by infiltration losses because evaporation losses and livestock consumption are of a much smaller order of magnitude. The total volume of infiltration amounted to over 90 percent of the water that entered each pond.

2.2. ESTIMATES OF INFILTRATION AND EVAPORATION

On three ponds (Ponds 10, 15 and 16) where estimates were made of livestock consumption, the percentages of losses by evaporation and infiltration as well as livestock consumption were estimated for the water remaining in each pond after the last substantial rain on September 12th. A summary of these calculations is presented in Appendix E. The results are shown in Table 2.1.

TABLE 2.1.

ESTIMATES OF INFILTRATION, EVAPORATION AND LIVESTOCK CONSUMPTION
(Volumes for 3 ponds after the final substantial rainfall of September 2 until drying)

Pond No.	Infiltration Loss % Total/Meters^3	Evaporation Loss % Total/Meters^3	Livestock Consumption % Total/Meters^3
10	92.6%/6400	4.8%/306	2.6%/167
15	77%/4843	6%/381	17%/1121
16	67%/6513	11%/1033	22%/2154

Pond 16 is considered locally to be one of the best ponds which is verified by these estimates. The estimate of livestock consumption for Pond 15 is based on optimistic estimates for the number of cattle using the pond. Pond 10 showed more rapid infiltration loss after the rainy season than 16 or 15 which is probably due to a sandy layer just below the pond bottom. These estimates present the severity of the infiltration problem.

2.3. FACTORS CAUSING HIGH INFILTRATION RATES

Observation of the substrata associated with the various ponds reveals possible causes of the high infiltration rates. Generally, the soils in the pond embankments have increasing clay content from top to bottom, with the top meter being sandy loam (approx. 15% clay) and the lower horizons being sandy clay loam (approx. 20% clay). Macropores less than 1 mm in diameter are observed with decreasing frequency from top to bottom. If the clays were expansive in nature (hence, low permeability) the pores would close when wetted. However, these are ancient, highly leached soils and their clays show little volume change upon wetting or drying so they would be expected to be reasonably permeable.

Ponds 10 and 22 (as well as 6 and 7 according to the equipment operator who excavated them) are underlain by layers of a medium sand of unknown depth which would certainly increase seepage rates. The excavation of sediment from Ponds 11, 12, 15, 19, and 25 revealed ancient stream beds from 5 to 15 meters in width bisecting the bottoms. These beds are also composed of a medium grained sand that is highly permeable.

Variations in the quantities of infiltration losses among the various ponds should be explainable by differences in the quantity of water entering each pond and by the differences in subsurface conditions. It appears that infiltration rates are greater the first few times a pond is filled and less later on. Further study, particularly of subsurface conditions would be necessary to draw definite conclusions about infiltration differences among ponds. Qualitatively it seems that Ponds 10 and 22, which are totally underlain by sand layers dry much more quickly than many of the other ponds (16, 25, L1, L4, L5) which have only a strip of sand running across the bottom. Ponds 6 and 7 also seem to dry exceedingly fast but they receive much less water than many other ponds. The ponds on the larger stream channels perform much better than those on the smaller ones both because of receiving larger quantities of water and because of relatively finer grained subsoil resulting in lower infiltration rates.

It seems reasonable to assume that a large portion if not the majority of infiltration losses occur through the sides as opposed to the bottoms of the ponds. The most obvious reason for this observation is that even with one meter of recently deposited sediment, much of it highly expansive clay, ponds exhibit high infiltration losses. A second factor is the relatively large area of the pond embankments compared with the bottom at full configuration. Even when considering a vertical projection onto a horizontal plane the area attributed to the sides is on the order of four times that of the bottom. Thus,

corrections to the problem should take the embankments into consideration as well as the bottoms.

2.4. METHODS FOR DECREASING INFILTRATION RATES

It would be desirable to reduce the infiltration losses of the existing ponds, however the standard methods for this would all be cost-prohibitive or inappropriate under the circumstances. Some of the techniques used to seal the bottoms of ponds are covering with a plastic liner, paving with asphalt or concrete, covering with clay (Bentonite), or mixing an additive into the soil such as sodium chloride.

Plastic liners need protection against cattle hooves and erosion damage, particularly at the inlets. This protection would need to consist of a 10 cm layer of lateritic soil overlain by a layer of rock and gravel that cattle could walk on. The cost of installing and protecting the liner would be on the order of $5,000. The inlet would need to be of the rock and mortar chute-type, be at least three times larger than those placed in four of the new ponds and cost approximately $15,000.

Asphalt pavement for a pond would cost $5,000 according to Jean Lefebvre, Inc. The inlet structure would still be required and the edges would need to be protected from erosion. It may also be necessary to place a plastic membrane below the asphalt. Concrete lining would be much more expensive than asphalt.

A clay coating on the pond embankments would need to be protected from erosion and cattle by a layer of rock and gravel. The sediment on the bottoms of the ponds may be appropriate to use on the sides but it consists of alternate layers of clay and sand. Care would be needed to assure a sufficiently high clay content. A full flow inlet structure would be required.

Sodium chloride is used successfully to seal ponds in various parts of the world. There is a minimum percentage of swelling clay necessary for this to be effective. The soils of the project ponds have a stable clay not appropriate for this technique.

If the ponds were lined they would require annual maintenance. This would require a long-term technical assistance program to work with the local people to teach them to be responsible for repairing any damage done to the linings. The materials appropriate to line the ponds are not available locally, and would be difficult or impossible to replace by villagers without outside assistance.

2.5. ALTERNATIVE POND DESIGNS

Alternative pond designs have been considered that would reduce infiltration losses. These include designs with impermeable linings and those utilizing different pit geometries.

The original pond design presented in the project design document (see Figure 2.1.) would lend itself well to lining with plastic, bentonite or asphalt. The plastic or bentonite would need to be covered with a layer of lateritic soil and finally with rocks and gravel as previously discussed. All dikes would need to be completely rocked on the sides to provide erosion protection. This type of pond would need to be on a reasonably small watershed (approximately 3 km^2) to avoid large floods that could wash them out. Proper location to assure filling without flooding would be difficult and involve a finite risk of failure. The cost of building these lined ponds would be at least one-half greater than the $32,000 paid for the contracted ponds.

The evidence that most of the infiltration losses occur through the pond embankments suggests that the more efficient pit geometries are those with reduced side area relative to the bottom area. The maximum of such reduction would be the use of vertical sides. These would slump without stabilization and therefore would need support from a retaining wall. Possibilities for this wall include sheet metal anchored into the embankment and a rock or concrete retaining wall. Sheet metal would be subject to rapid deterioration and corrosion. The cost of installing and maintaining either of these structures makes them impractical.

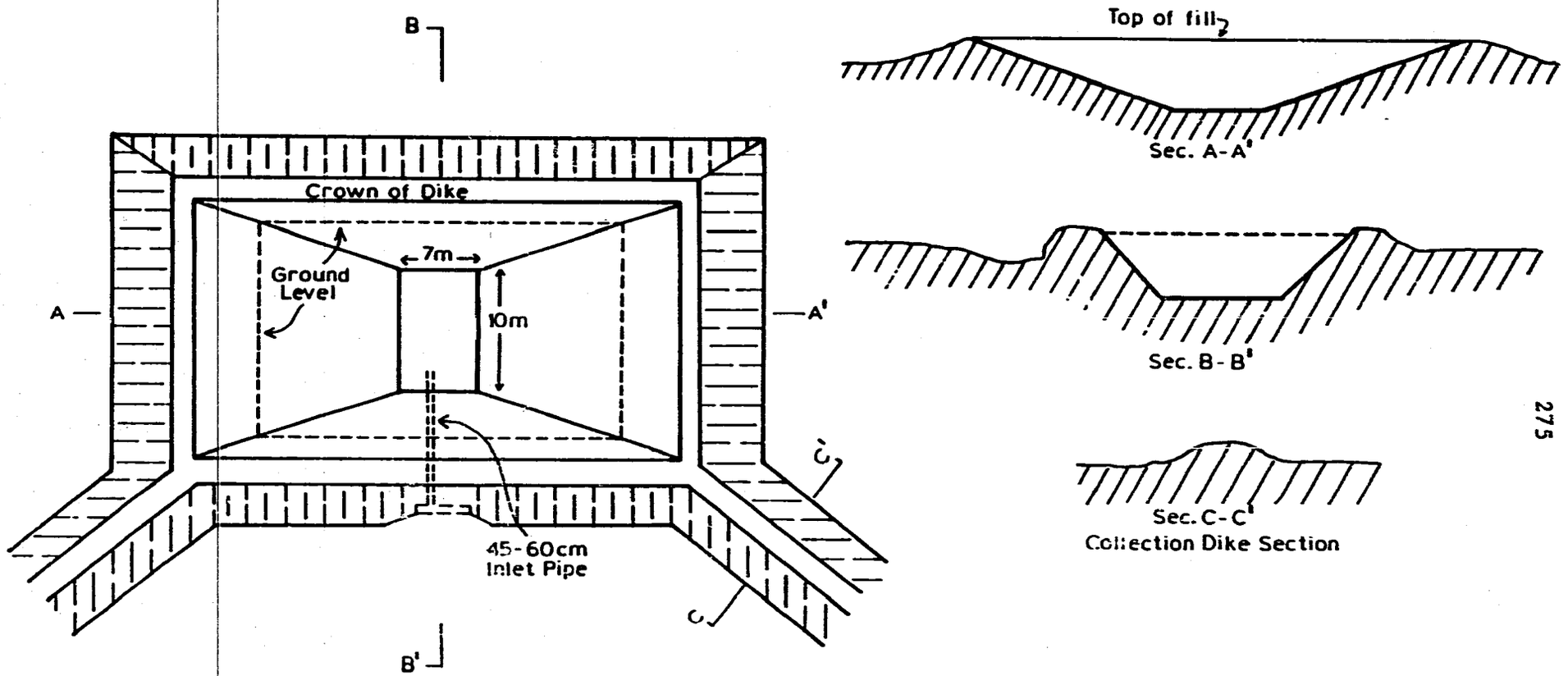
The steepest slopes that would be stable are one on two. If more ponds are to be built, this is the maximum slope that should be used to assure that the embankments will not collapse into the pond. There would probably not be a significant difference between the infiltration with one on two slopes, compared with one on three slopes.

Constructing the ponds shallower with greater bottom surface area is another modification meriting discussion. The primary drawback of this alternative is that the upper soil layers are more permeable than the lower increasing the overall possibility for infiltration through the pond sides and bottom. Evaporation would increase due to the increase in water surface area. These factors would probably negate the advantage of a decreased side area to bottom area ratio.

2.6. GEOTECHNICAL STUDIES

If it is desired to build unlined ponds in other areas of West Africa, subsurface studies should be performed to avoid problems with infiltration. If there are existing ponds in the

Figure 2.1. POND DESIGN IN THE ORIGINAL PROJECT DOCUMENT



area their performance should be studied along with the substrata to reveal local conditions and problems.

The basic procedure that needs to be followed before excavating a pond in an unknown area is the boring of holes at the perspective site to at least one meter below the intended pond depth. A particle size determination should be made on each encountered soil layer which will yield the percentage of clay, sand and silt. The shrink/swell properties of the clay fraction should be studied which will indicate the relative water permeability of the soil when considered with the particle size analysis. Undisturbed samples of soil should be studied for the existence of plant or animal-created pores. The permeability of each layer should be determined either with infiltration trials in the field or determinations with undisturbed core samples in the laboratory.

Where subsurface conditions are little known in an area, several test bores should be drilled for each pond. With experience the number could either be increased or decreased depending on the variability of the conditions encountered.

2.7. STORM RUNOFF VOLUMES

For some rains in various ponds it was possible to estimate the volume of runoff and calculate a runoff coefficient for the appropriate watersheds. These results are presented in Table 2.2. The storms that yielded significant runoff were typically intense thundershowers. It is obvious that ponds with larger watersheds are much more likely to fill than ponds on smaller watersheds. Ponds seem to perform better in Type 2 soil than in Type 1, due to lower infiltration rates, steeper slopes, fewer natural ponds, as well as larger watershed areas. Pond 1 appears to be an exception in that it seems to perform better than other ponds in Type 1 soil. This judgement is based on observations by project personnel from previous years since little data was taken from the site during the study. The relatively high runoff rate likely results from some slopes running north to south into the main stream channel that are approximately 1% as opposed to the 0.1% characterizing most of the other areas. Further data is required if more detailed information concerning runoff is desired.

2.8. SEDIMENTATION

Estimates of pond sedimentation rates were previously presented in Table 1.4. The ponds with the highest rate of sedimentation are those that receive the least amounts of water. The sides of these ponds are highly eroded by gullies indicating that a major

TABLE 2.2.

RUNOFF VOLUMES AND COEFFICIENTS FOR SELECTED RAINFALL EVENTS

Pond No.	Date	Precipitation (mm)	Runoff Volume(M^3)	Watershed Area(Km^2)	Percent Runoff
1	6/17	52	7000+	5	2.6%[b]
6	6/17	48	800	6	0.28
6	7/9	85	7100	6	1.4
6	8/3	63	1000	6	0.26
6	8/24	52	450	6	0.14
6	9/12	80	750	6	0.15
7	6/17	72	6400	4	2.2
7	7/9	85	1600	4	0.47
7	8/2	61	1600	4	0.65
7	9/12	83	1000	4	0.30
10	6/11	18	1900	14	0.75
10	6/17	52	5000+	14	0.69[b]
10	8/24	42	3400	14	0.58
10	9/12	77	6000+	14	0.56[b]
11	6/20	40	6000+	22[a]	0.68[b]
11	8/3	47	1200	22[a]	0.12
11	9/12	115	5500	22[a]	0.22
12	6/17	40	3600	35	0.26
15	8/24	66	700	27	0.04
15	9/12	92	5400	27	0.22
16	6/11	40	5200	8	1.6
16	6/17	60	4100	8	1.2[b]
16	8/21	60	6000+	8	0.8[b]
16	9/12	75	7000	8	1.1
19	6/17	54	3600	14	0.48
22	6/26	27	5000+	6.6	2.8
22	7/21	22	3500	6.6	2.4
22	8/21	56	5300	6.6	1.4
L2	8/23	94	1500	10	0.16
L2	9/12	60	1100	10	0.18
L2	6/17	66	2400	10	0.36
L3	7/9	80	4000+	12	0.42
L3	8/3	22	250	12	0.09
L3	8/22	47	375	12	0.07
L3	8/31	50	500	12	0.08
L3	9/12	80	600	12	0.06
L4	7/9	80+	8000+	18	0.5
L5	8/21	56	900	56[a]	0.03

NOTES: [a]For these rainfall events upstream ponds did not spill resulting in smaller than the total watershed areas.

[b]The ponds overflowed in these events making estimated runoff volumes and coefficients low.

source of sedimentation is from the pond sides. Ponds with low rates of sedimentation are filled several times during the rainy season. The most obvious example of this is Pond 11 which exhibited the least sediment. The spoils pile of this pond acts as a dam thirty meters downstream from the pit. At full configuration the pit is completely inundated and is not visible because of a large lake of water backed several hundred meters up the watershed. Thus, when rainfall occurs little sediment is deposited in the pond because it settles out on the edges before reaching the center. For this reason downstream spoils piles seem to be a better design than side spoils piles. Full ponds are also effective in controlling erosion. Therefore ponds tend to function better on the larger watersheds (which keep ponds fuller) than on smaller ones. The dams can break as happened on the large July 9th rain at several ponds but that was only the second occurrence of this nature since the first pond was constructed. Repairing the breaks required approximately 8 hours of bulldozer time (814) per pond. Pond 1 is again an exception in that it seems to fill and yet has a high rate of sedimentation. This is probably caused by erosion off the spoils pile which forms a high half circle around the downstream portion of the dam. It would have been better to construct a lower, shorter dam which would result in less sedimentation.

3. CONCLUSIONS AND RECOMMENDATIONS

The ponds were designed to function with infiltration and evaporation losses at 35%. For most ponds infiltration and evaporation losses account for over 80% of the water remaining in the ponds after the last rain. The best possible case was 22% of the water stored in Pond 16 was used by livestock.

Mitigation of these problems is not recommended at the present time because of expense and the maintenance requirements after construction. The input of additional funds for this purpose would result in a lost investment.

The conclusion is that thorough hydrologic and geotechnical studies are required before proceeding with expensive structures. In the case of this area they would have revealed permeable subsoil conditions that make pit pond construction unattractive.

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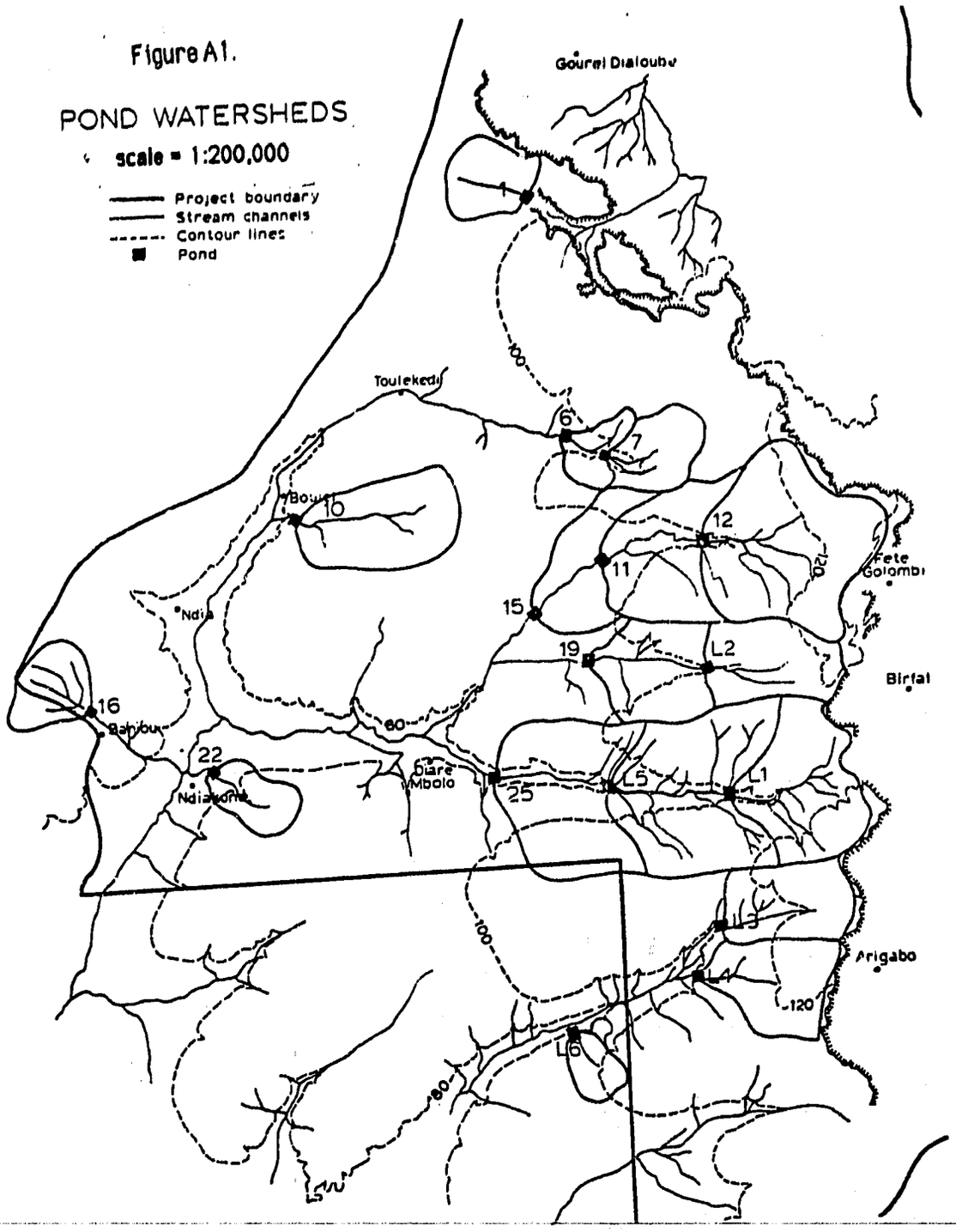
APPENDIX A

1:200,000 POND WATERSHED MAP



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APPENDIX B

SOIL DESCRIPTIONS*

Pit Number 1 (see Figure 1.2.)

Slope: 0 - 0.5% Physiography: Plateau
Stoniness: littered with ironstone gravel
Drainage: excessive
Horizons:

A 0 - 22cm Dry Color: 7.5YR6/2, Moist Color: 10YR3/2
Texture: Gravelly Loam (75% Sand, 8% Silt, 17% Clay)
Structure: weak granular, Consistence: slightly hard when dry, friable when moist, sticky when wet
Lower Boundary: abrupt

C1 22- 47cm Dry Color: 5YR6/6, Moist Color: 5YR4/6
consists of partially hardened plinthite
Structure: massive
Lower Boundary: gradual

C2 47cm+ Solid Ironstone with pores that appear discontinuous

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*These descriptions use United States Dept. of Agricultural, Soil Conservation Service Terminology.

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Pit Number 2

Physiography: Flood plain above drainage channel
Slope: 0 - 3%
Stoniness: None
Drainage: good
Horizons:

A 0-16cm Dry Color: 10YR6/2, Moist Color: 10YR4/2
Texture: Sandy Loam (78% Sand, 7% Silt, 15% Clay)
Structure: massive Consistence: slightly hard when dry, very friable when moist, slightly sticky when wet.
Lower Boundary: abrupt

B 61-41cm Dry Color: 10YR6/3, Moist Color: 10YR4/4
Texture: Sandy Clay Loam (67% Sand, 10% Silt, 23% Clay) Structure: massive, Consistence hard when dry, friable when moist, sticky when wet.
Lower Boundary: abrupt

C1 41-70cm Dry Color: 10YR7/4, mottles 10R5/6, Moist Color:
Moist Color: 7.5YR5/4, mottles 10R5/8
Texture: Sandy Clay Loam (55% Sand, 13% Silt, 32% Clay)
Structure: massive, Consistence: hard when dry, very friable when moist, slightly sticky when wet.
Lower Boundary: clear

C2 70-130cm Dry Color: 10YR8/2, mottles 10R5/6
Moist Color: 7.5YR5/4, mottles 10R5/8
Texture: Sandy Clay Loam (60% Sand, 12% Silt, 28% Clay)
Structure: massive,, Consistence: hard when dry, very friable when moist, slighty sticky when wet.
Lower Boundary: clear

C3 140cm+ Dry Color: 5YR8/1, mottled, Moist Color: 10YR7/2, mottled,
Texture: Sandy Clay Loam (51% Sand, 14% Silt 35% Clay)
Structure: weak subangular blocky Consistence: hard when dry, extremely firm when moist, sticky when wet.

APPENDIX C

RAINFALL DATA AND MAPS

TABLE C1.

RAINFALL CHART
(mm)

Gauges \ Date	5/27	6/11	6/17	6/20	6/26	7/2	7/8	6/9	7/21	8/3	8/10	8/11	8/14	8/22	8/24	8/30	9/1	9/12	9/18	10/3	10/6
1			76	1	33	0			37	7	15										
A										3	16	1	1	6 3							
B										2	21	6	1	6 8			1 2				
C			75		27	0	6	38	50	0	15	4	10	60	25	5	28	60	8	8	12
D					25	0	0	39	54	0	14	5									
E			75		16	0			44	0		4									
F			83		9	0			45		16	6									
G									44	8	5	2	9	56	22	3	27				
H								+40	37	7	5	1	7	56	24						
K	8	40	64	1	37	0	8	36		5	5	5	17						10		
2			90		2	0	1	+40	41	2	14	8	2	6 2		1 3					
3	20	20	108	8	7	6	13	43		0	4	12									
4			74		0	0			16	14	0	0	30	4 3		1 5					
5			38						0												
6		18	52		4	20		+57	8	33	0	0	10			6		77	4		19
7			73		3	1		+56	4	21	0	0	2	4 2		1 6					
8										20		0									
9			74			5			14		2		4	5 6		2 3					
11			52			1		+54	24	18	0	9	9	5 5		2 2					
12						5			15	22	0	4	0	6 6		12	19	93	4	11	9
13			40	1		8			8	47	0	0	2	5 2		9	23	115	9	37	16
14			42			11			4	47	0		2	2 8		7					
15			48							63	0		4	5 2		14	19		10	31	16
16			65						4	67	0		5			9					
17		19	72					83	8	61	0	0	12	4 4		20	18	83	8	0	1
18			51			1		+80	6	42	0		6	2 5		2	15				
19			40			9		+59	7	29	0		3	5 8		12	18	79	11	19	
20			38																		
21		40	54	3					29	13		2	11	9 1		9	17	92	9	9	21
22									25	34	2	12	20	9 4				120			
23			26		4			+78	30	13			18			36	10				
24		28	11					+68	23	21	1	3	20	58	0			59	12	2	17
25		44	50		22			52	29	26	3	10	28	54	0	10	16	0	6	33	
26			14						13	26	2	15		6 0				37			
27		15	11		10			+75	32	10	1	3	12			4 3					
29					23					28		10	7								
30					23			+44	17	20	0	12	11	43	25				19		
31					34				20	14	2	9	7	55	25	2	22				
32		27	40		27	0			22	14	5	4	11	56	17	9	19	42			
35			52				23														
36			48				23	83													
37		10	31				10	52													
38			12		13			+60	44	22	4	0	18	47	0	5 2		80	23	5	
39									31	6	0	6	7	35		5 4		65	24	6	
40									38	16	0	0	18	35		6 6		93	23	9	

NOTES: A bar over a number through two columns indicates the combined rainfall of two successive rains |6|6|.

Missing data indicates a gauge down or missing/lost/stolen.

+ indicates approximate.

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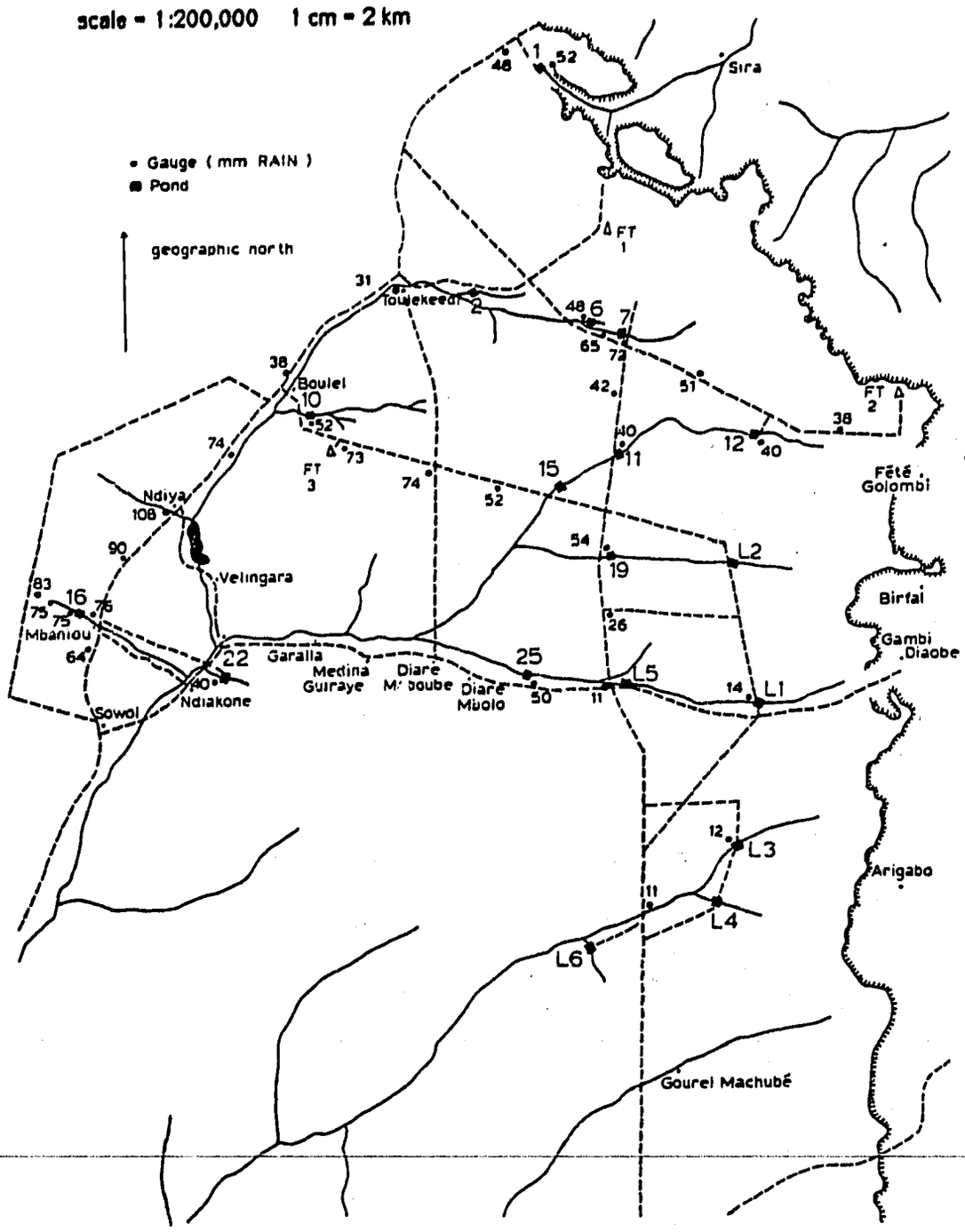
Figure C2. Rainfall Distribution

scale = 1:200,000 1 cm = 2 km



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APPENDIX D

POND WATER VOLUME VERSUS TIME CURVES

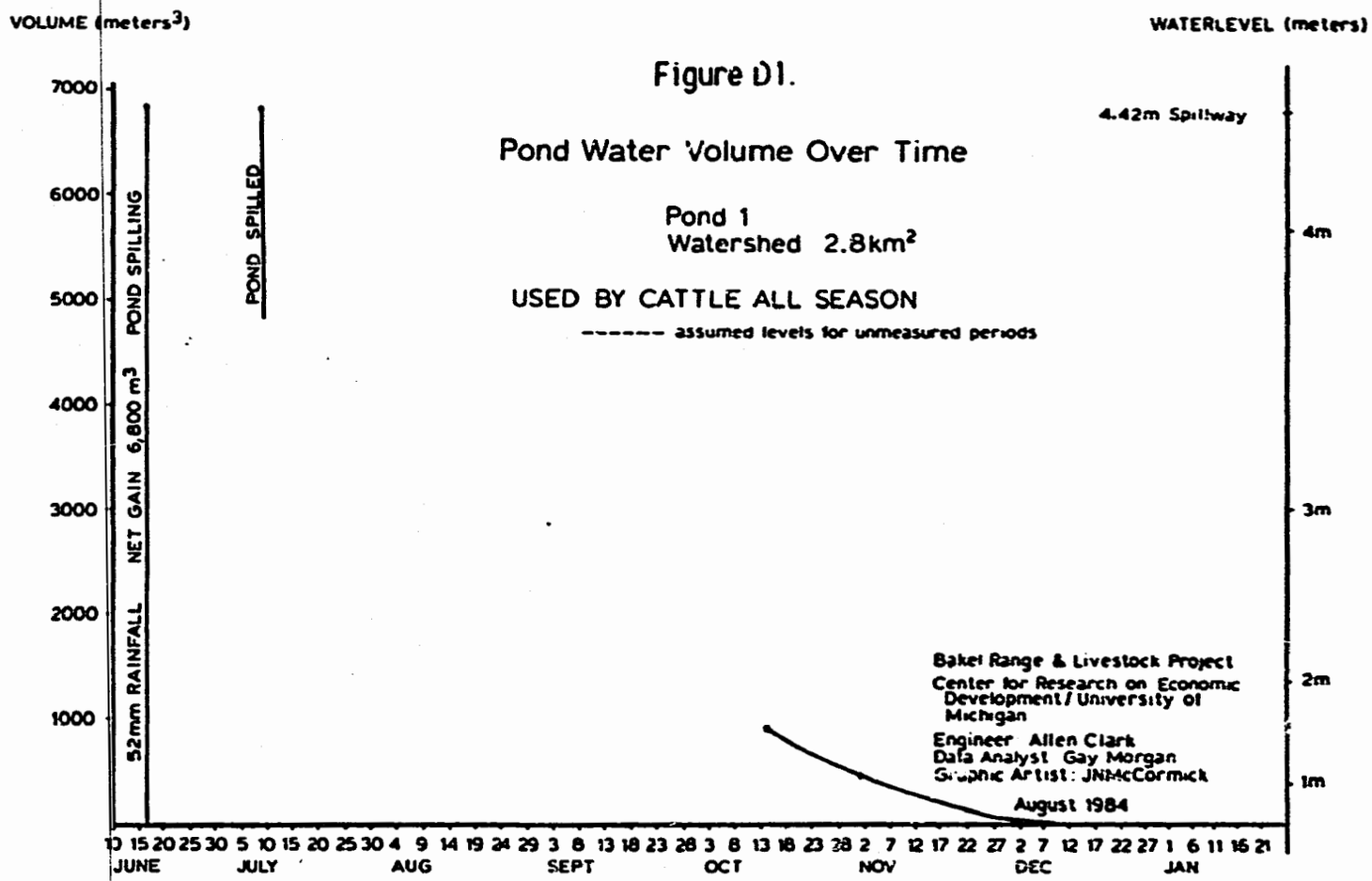

Figure D1.

Pond Water Volume Over Time

Pond 1
Watershed 2.8km²

USED BY CATTLE ALL SEASON

------ assumed levels for unmeasured periods

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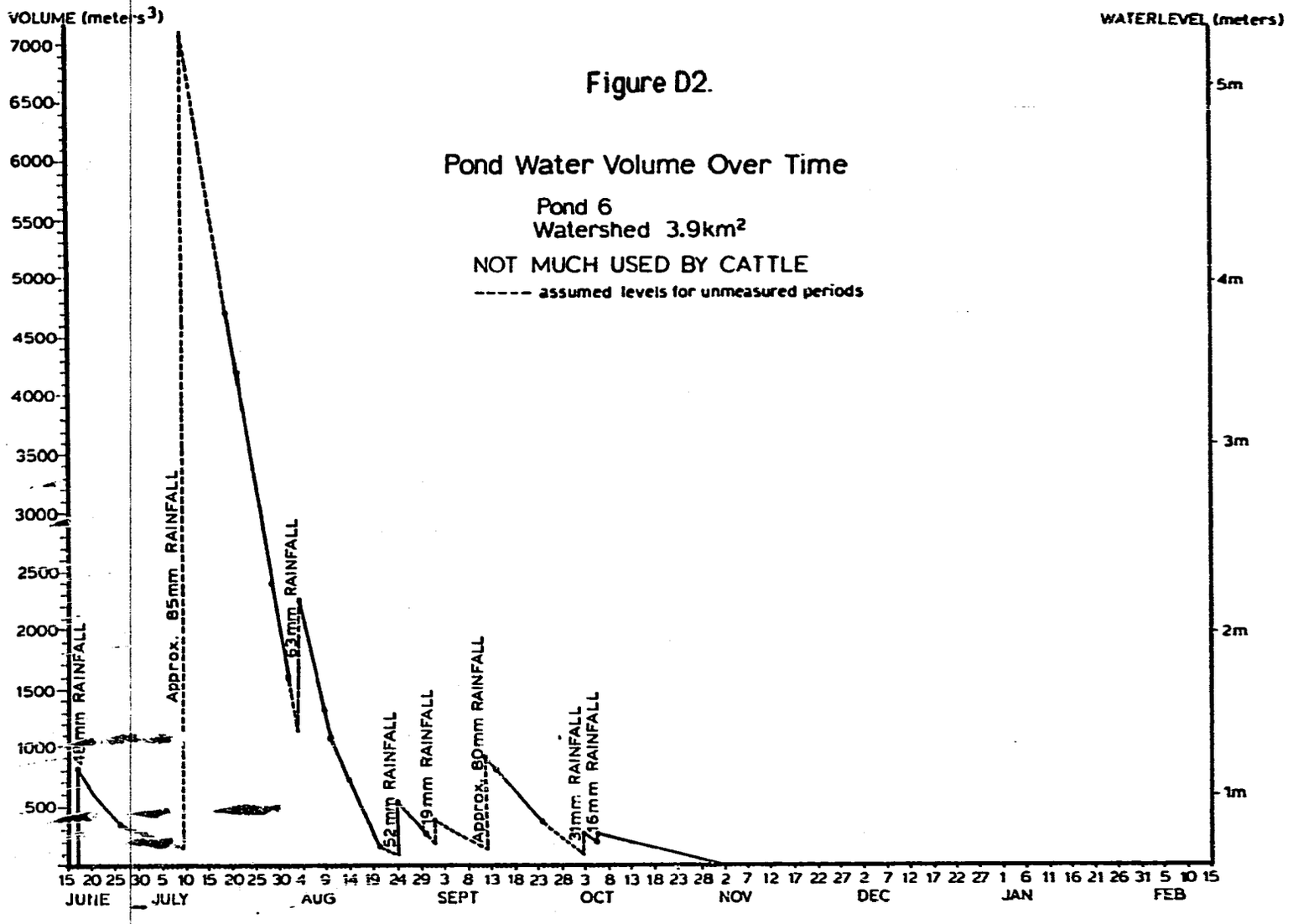


Figure D2.

Pond Water Volume Over Time

Pond 6
Watershed 3.9km²

NOT MUCH USED BY CATTLE

----- assumed levels for unmeasured periods

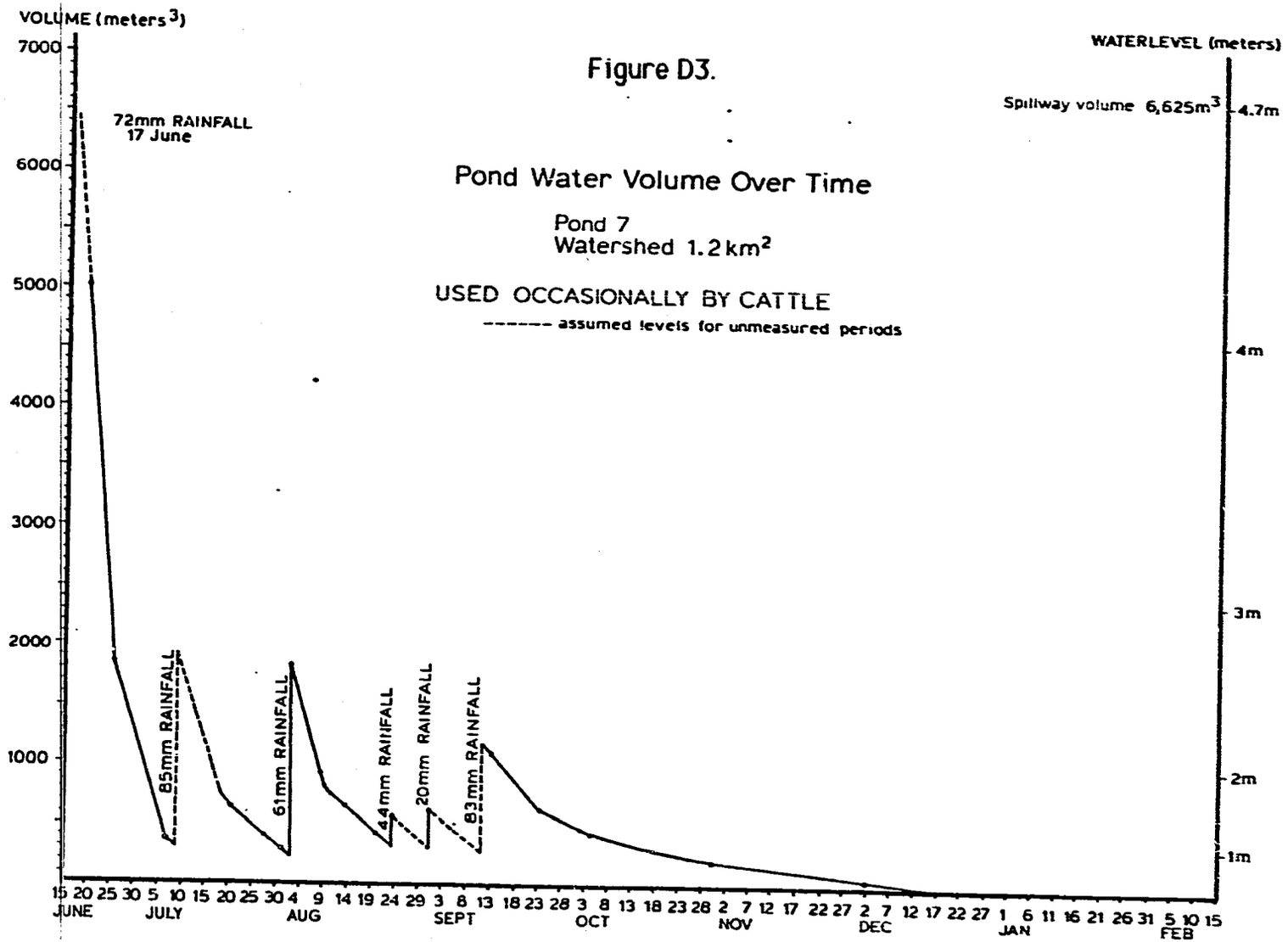


Figure D3.

Pond Water Volume Over Time

Pond 7
Watershed 1.2 km²

USED OCCASIONALLY BY CATTLE

------ assumed levels for unmeasured periods

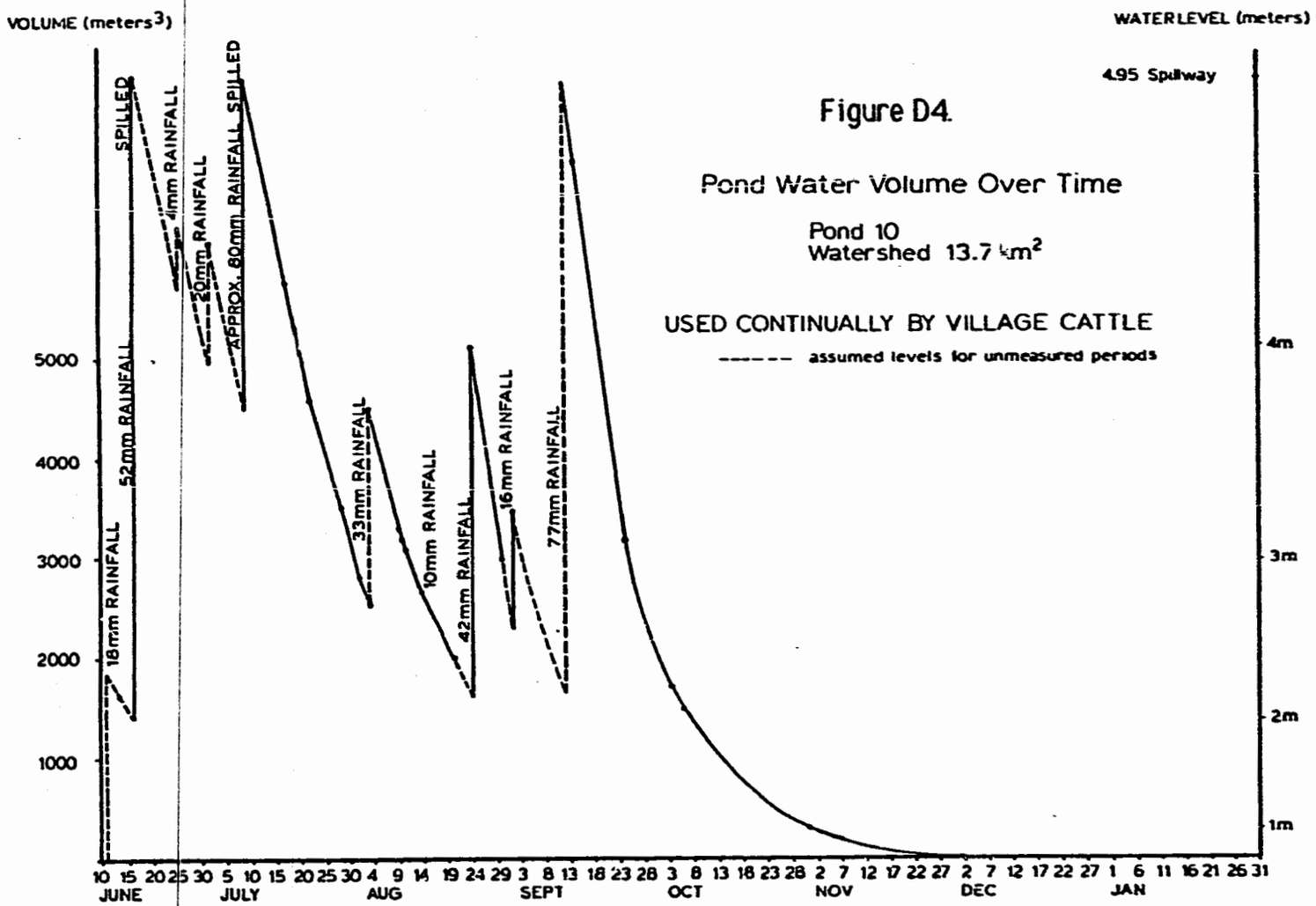


Figure D4.

Pond Water Volume Over Time

Pond 10
Watershed 13.7 km²

USED CONTINUALLY BY VILLAGE CATTLE

------ assumed levels for unmeasured periods

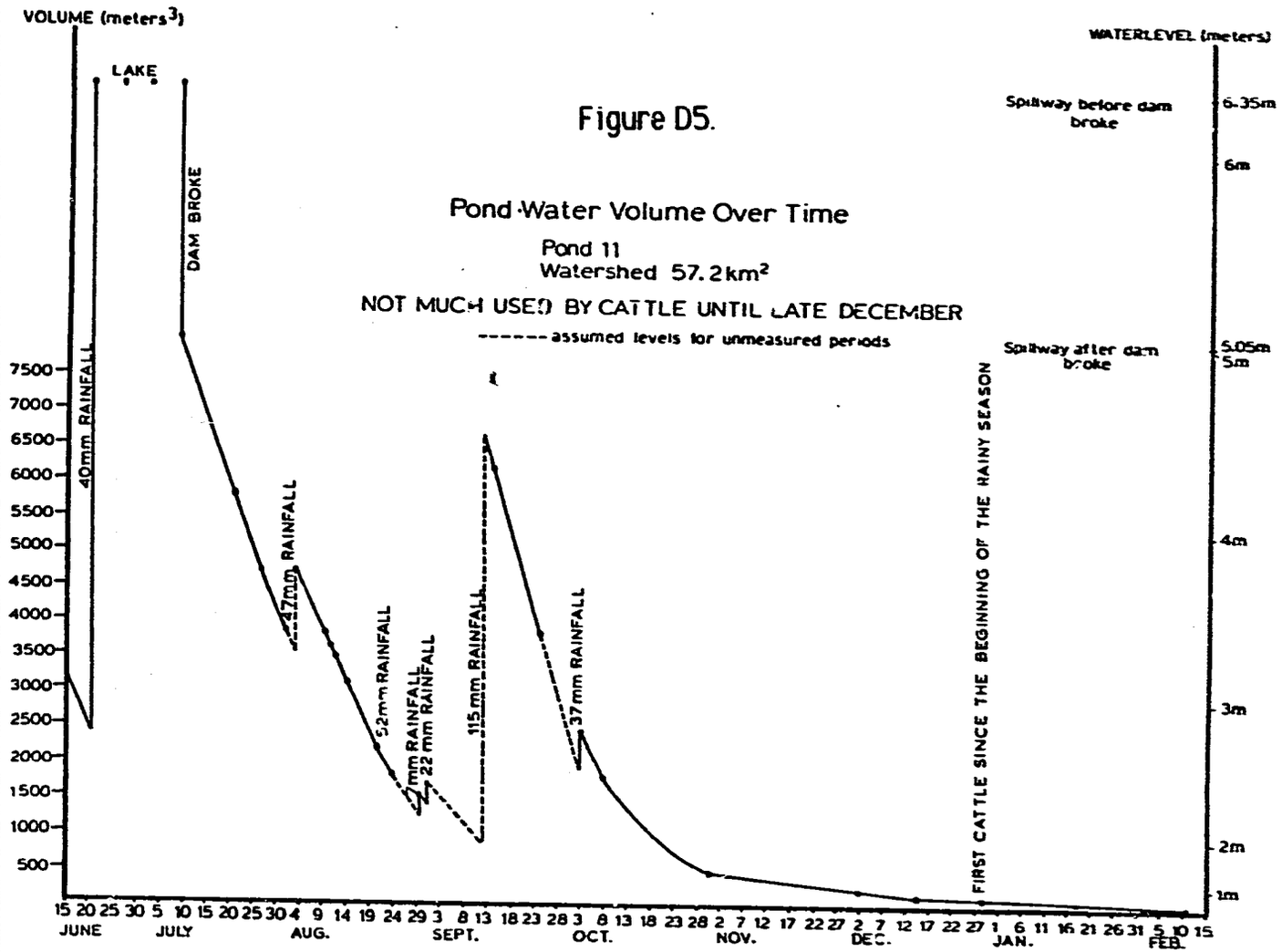


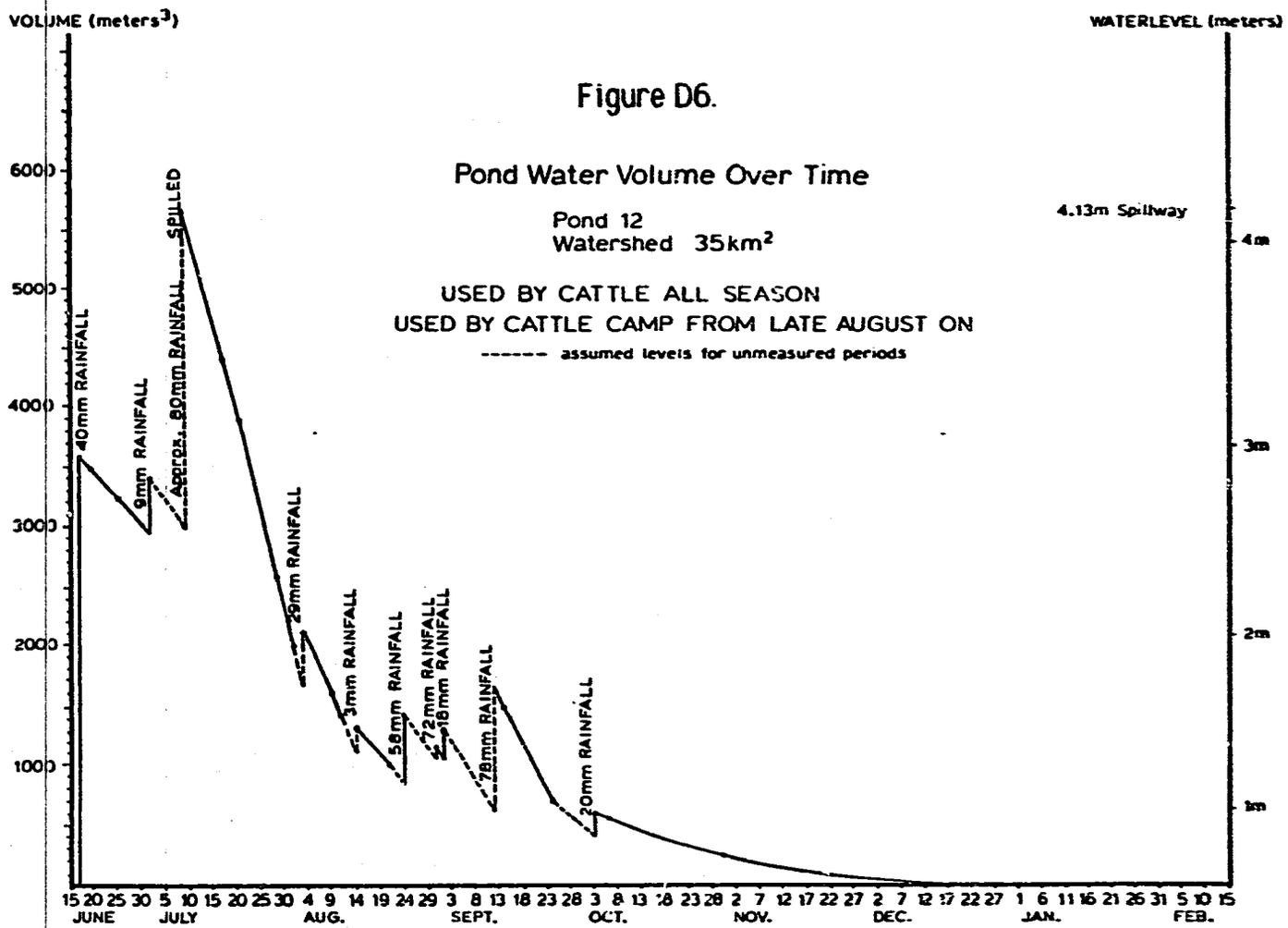
Figure D5.

Pond Water Volume Over Time

Pond 11
Watershed 57.2km^2

NOT MUCH USED BY CATTLE UNTIL LATE DECEMBER

------ assumed levels for unmeasured periods


VOLUME (meters³)
WATERLEVEL (meters)
Figure D6.
Pond Water Volume Over Time
Pond 12
Watershed 35km²
USED BY CATTLE ALL SEASON
USED BY CATTLE CAMP FROM LATE AUGUST ON
------ assumed levels for unmeasured periods
4.13m Spillway
40mm RAINFALL
9mm RAINFALL
Approx. 80mm RAINFALL
SPILLED
29mm RAINFALL
3mm RAINFALL
58mm RAINFALL
72mm RAINFALL
18mm RAINFALL
78mm RAINFALL
20mm RAINFALL
6000
5000
4000
3000
2000
1000
4m
3m
2m
1m
15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29 3 8 13 18 23 28 3 8 13 18 23 28 2 7 12 17 22 27 2 7 12 17 22 27 1 6 11 16 21 26 31 5 10 15
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.

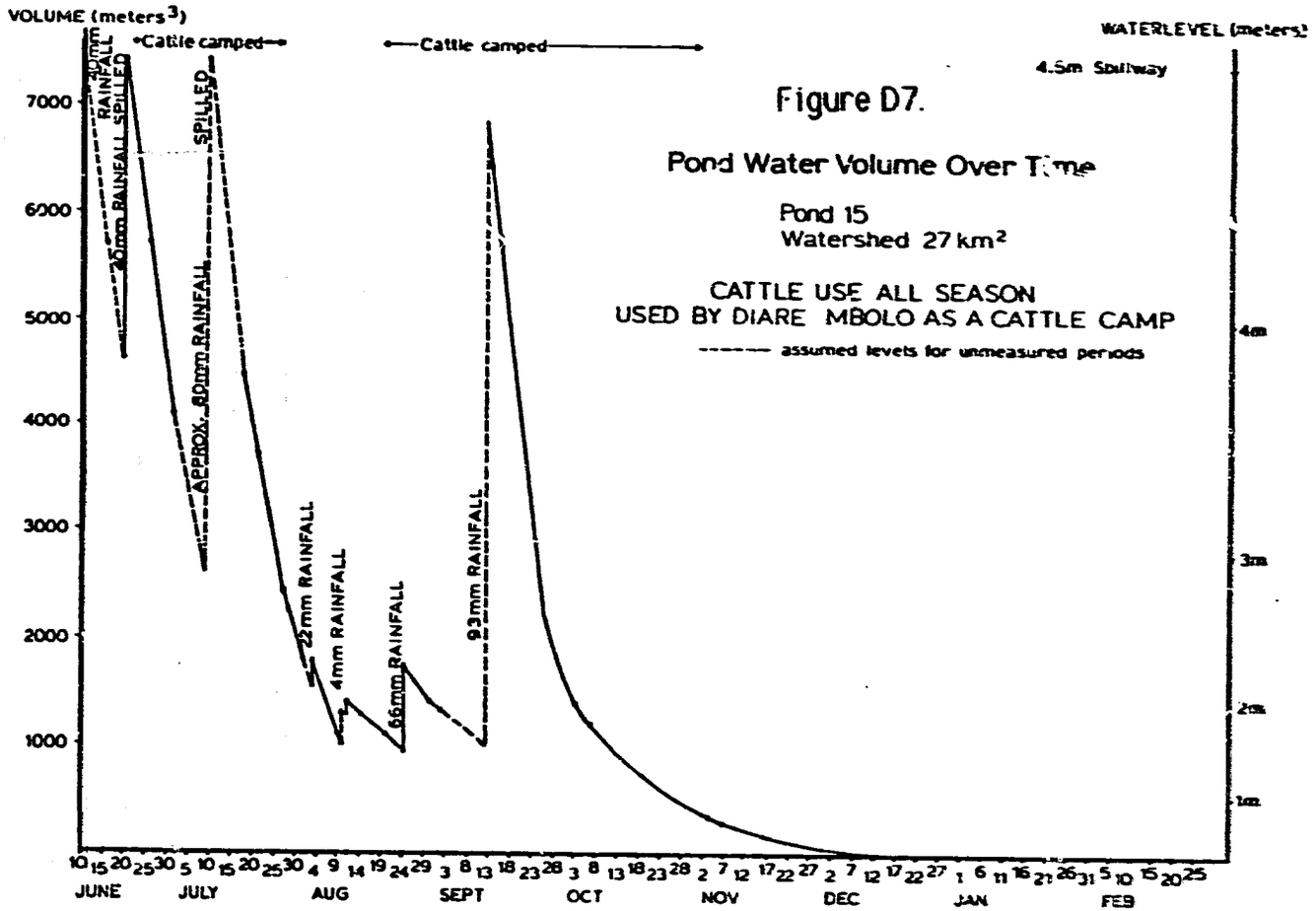

VOLUME (meters³)
WATERLEVEL (meters)
4.5m Spillway
Cattle camped
Cattle camped
20mm RAINFALL
20mm RAINFALL SPILLED
SPILLED
APPROX. 80mm RAINFALL
22mm RAINFALL
4mm RAINFALL
66mm RAINFALL
93mm RAINFALL
7000
6000
5000
4000
3000
2000
1000
4m
3m
2m
1m
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
Pond Water Volume Over Time
Pond 15
Watershed 27 km²
CATTLE USE ALL SEASON
USED BY DIARE MBOLO AS A CATTLE CAMP
assumed levels for unmeasured periods

Figure D7.

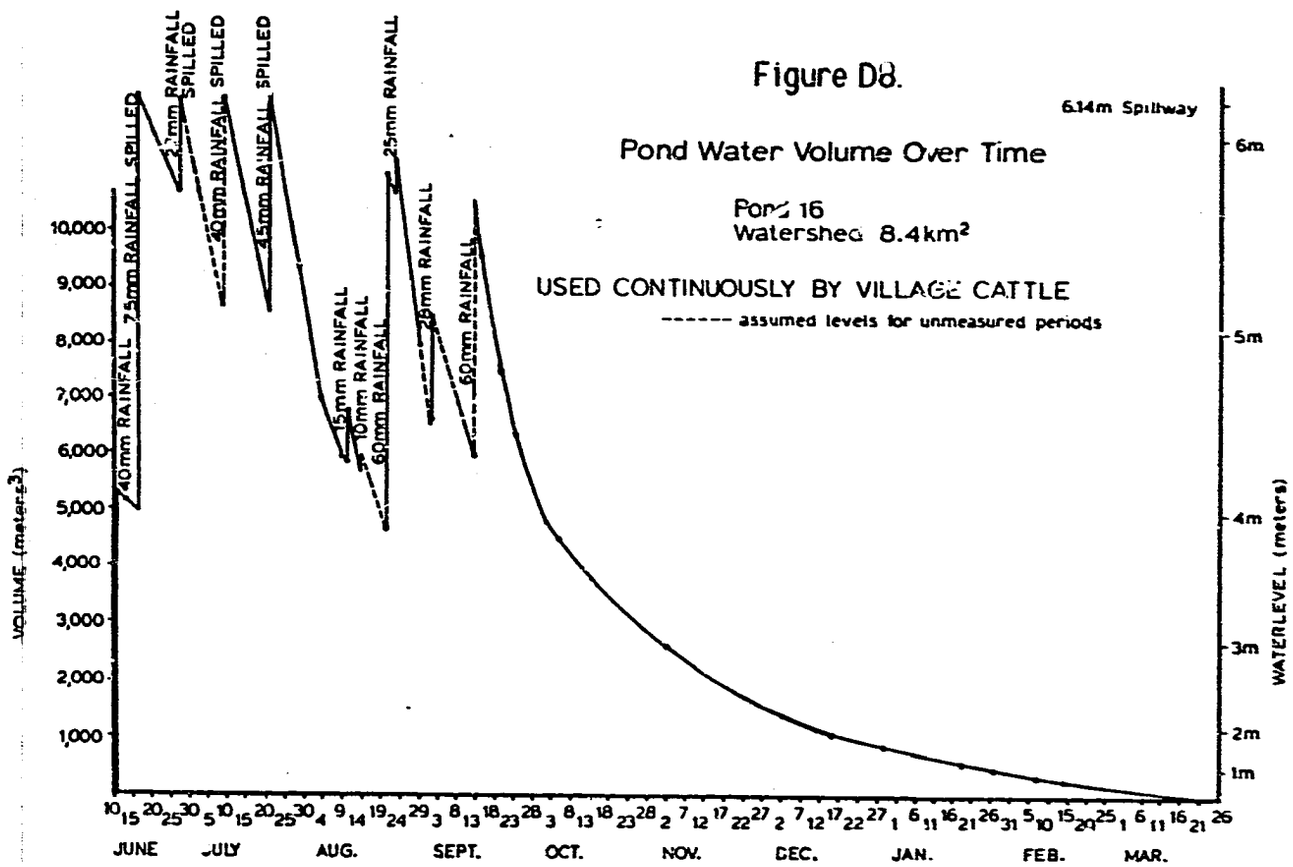


Figure D8.
Pond Water Volume Over Time
Pond 16
Watershed 8.4km²
USED CONTINUOUSLY BY VILLAGE CATTLE
------ assumed levels for unmeasured periods
6.14m Spillway
40mm RAINFALL SPILLED
7.5mm RAINFALL SPILLED
40mm RAINFALL SPILLED
45mm RAINFALL SPILLED
15mm RAINFALL
10mm RAINFALL
60mm RAINFALL
25mm RAINFALL
28mm RAINFALL
60mm RAINFALL
VOLUME (meters³)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
WATERLEVEL (meters)
6m
5m
4m
3m
2m
1m
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.

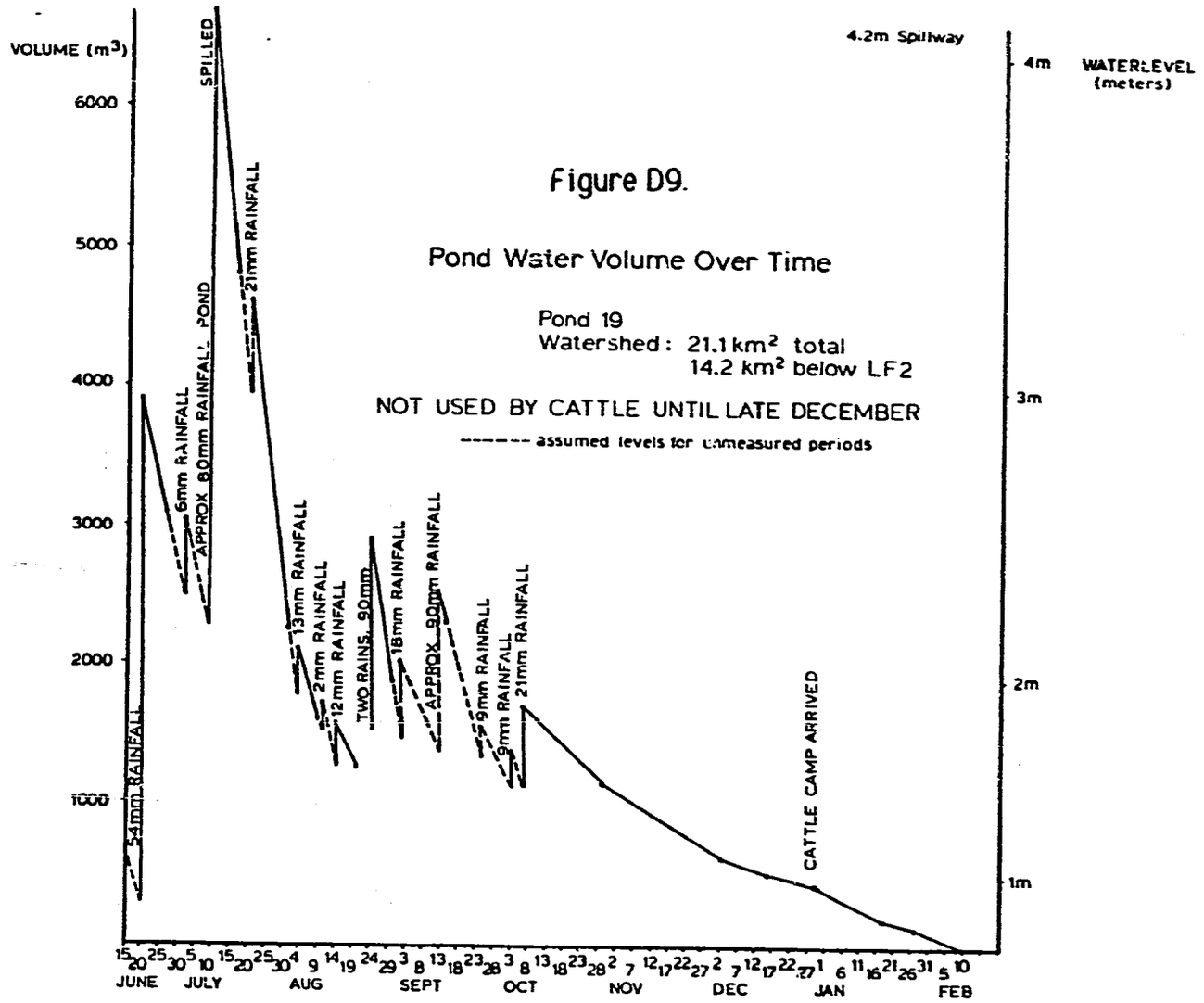


Figure D9.

Pond Water Volume Over Time

Pond 19
Watershed: 21.1 km² total
14.2 km² below LF2

NOT USED BY CATTLE UNTIL LATE DECEMBER

------- assumed levels for unmeasured periods

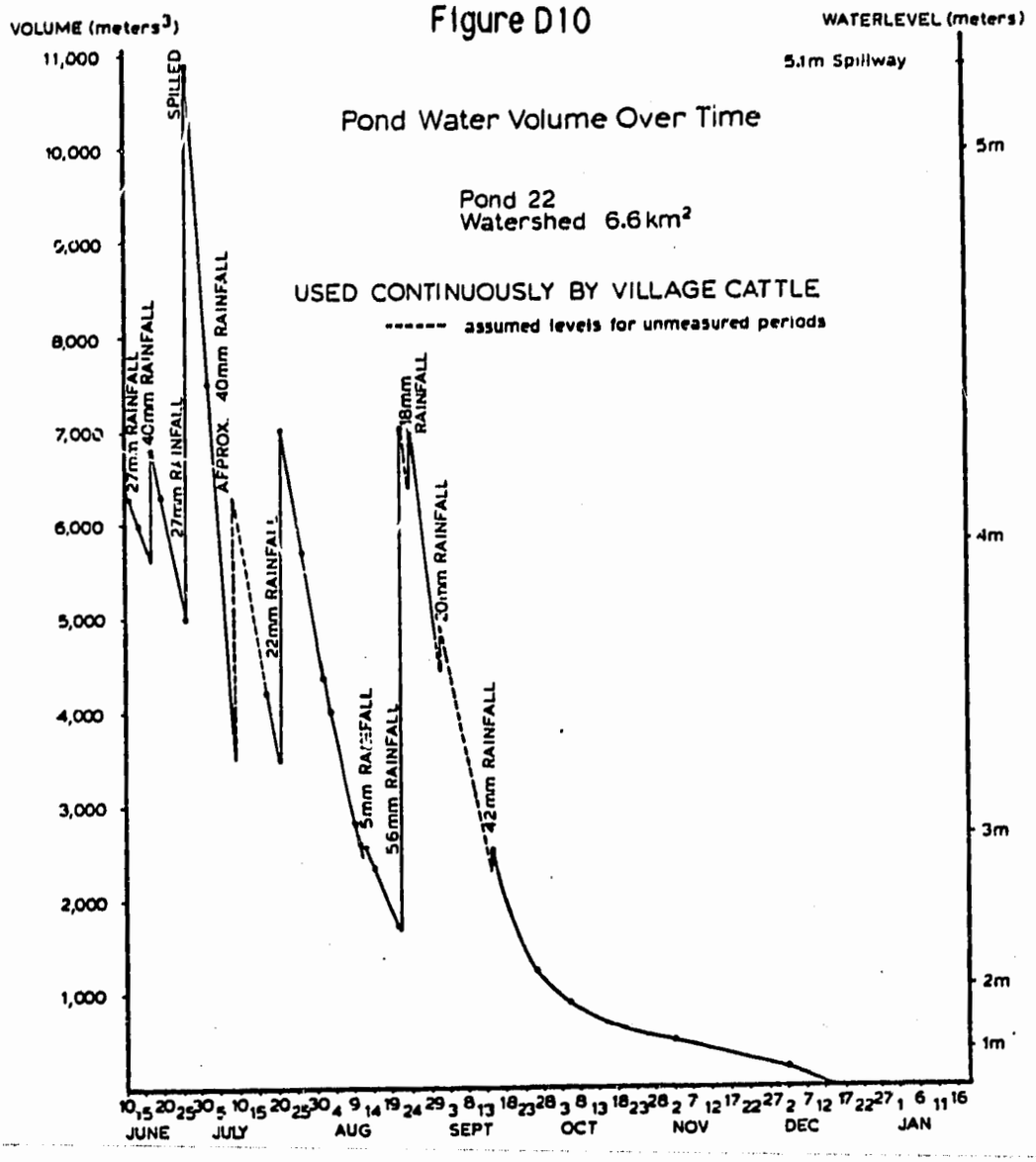


Figure D10
Pond Water Volume Over Time
Pond 22
Watershed 6.6 km²
USED CONTINUOUSLY BY VILLAGE CATTLE
------ assumed levels for unmeasured periods
VOLUME (meters³)
WATERLEVEL (meters)
5.1m Spillway
SPILLED
27mm RAINFALL
40mm RAINFALL
27mm RAINFALL
APPROX. 40mm RAINFALL
22mm RAINFALL
5mm RAINFALL
56mm RAINFALL
18mm RAINFALL
20mm RAINFALL
42mm RAINFALL
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN

Figure D11.

Pond Water Volume Over Time

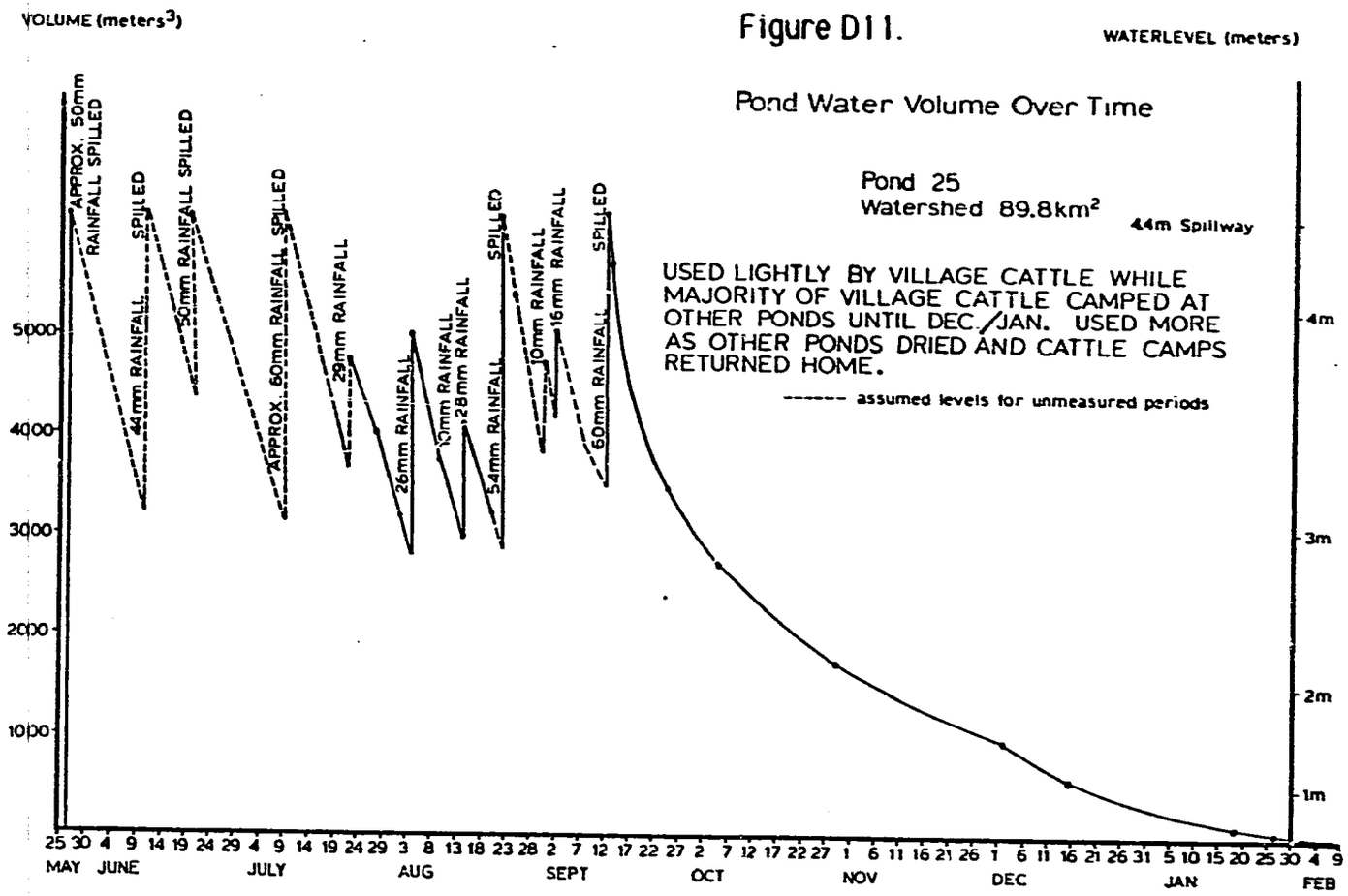
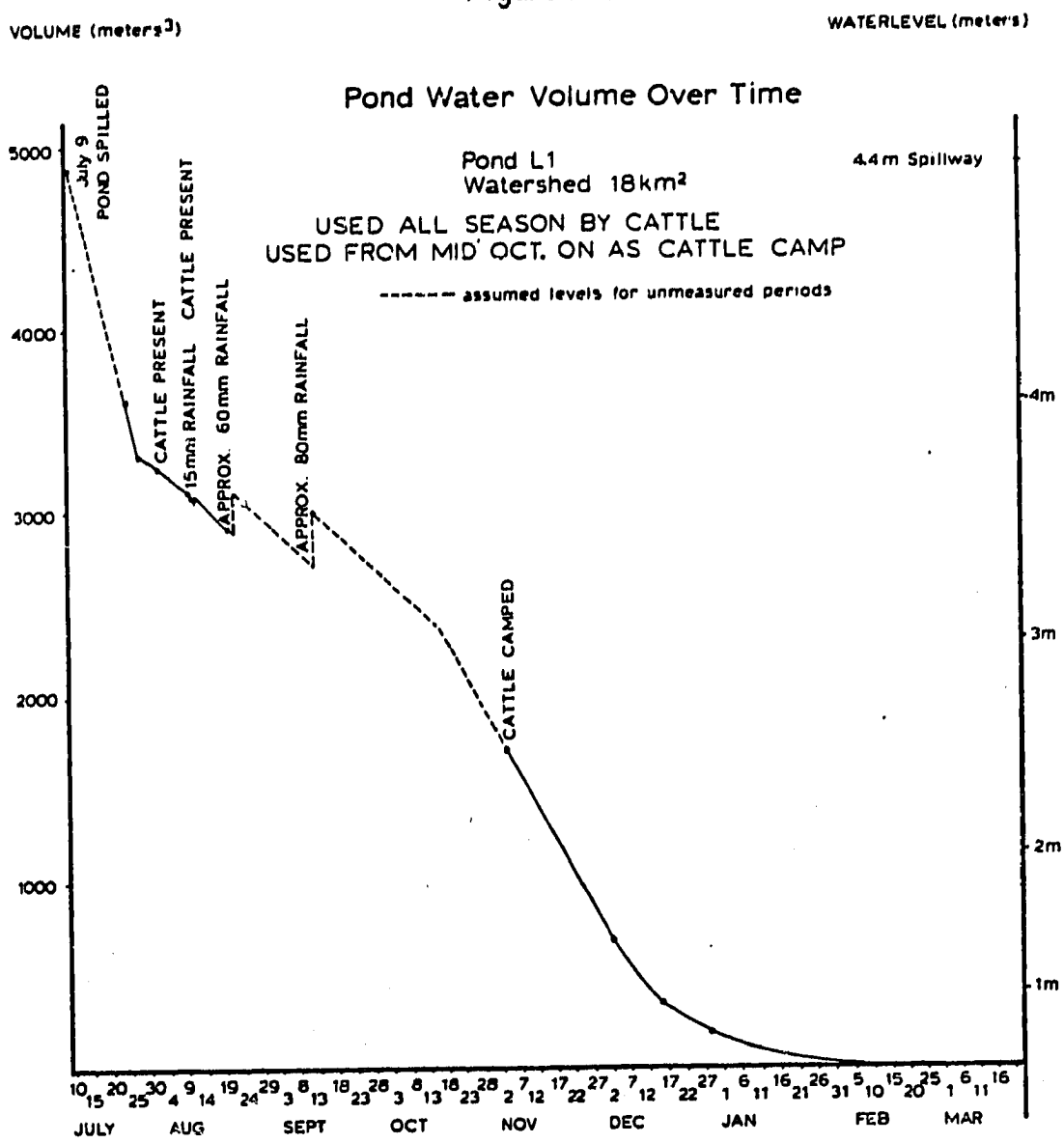
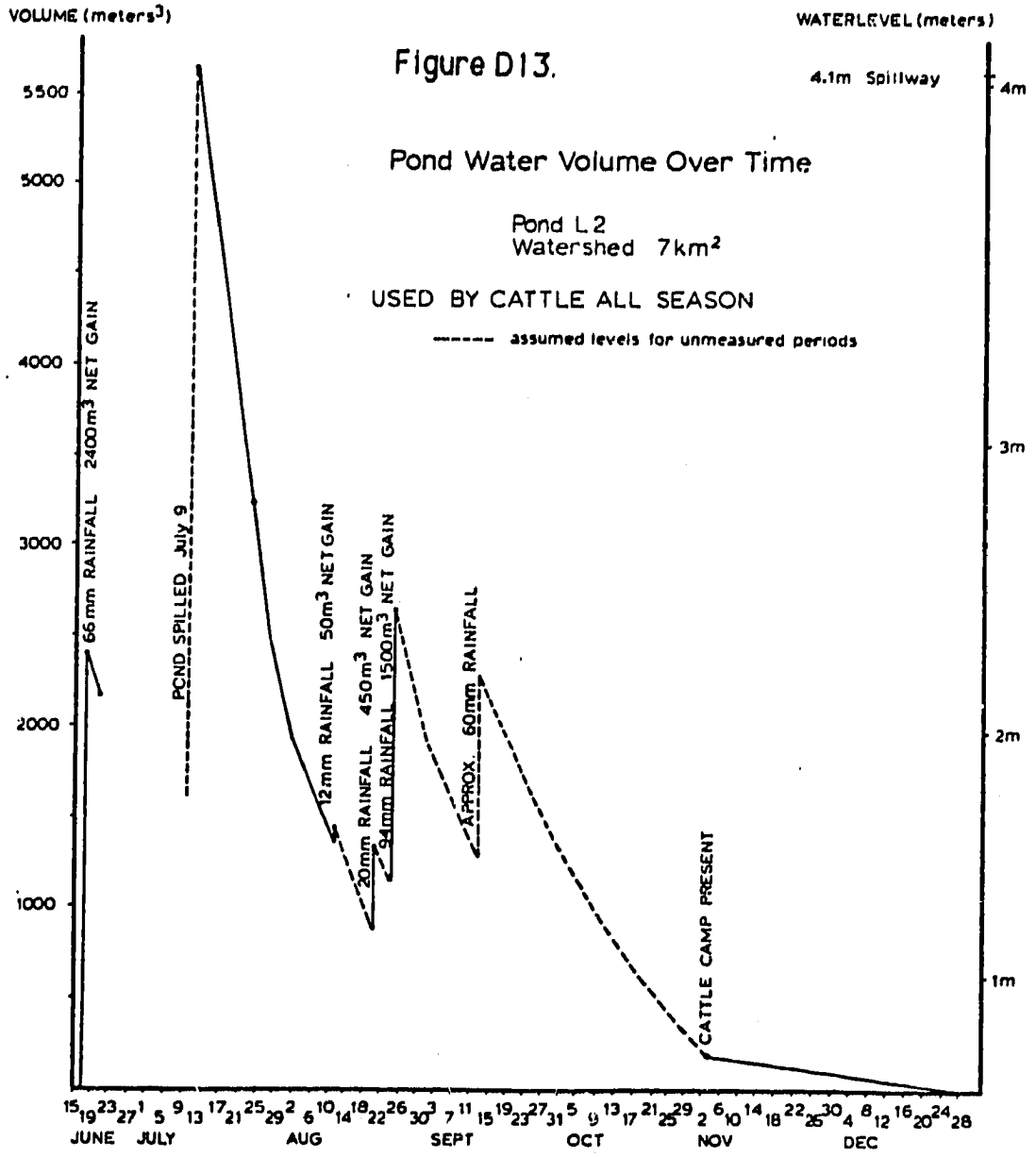


Figure D12.


VOLUME (meters³)
WATERLEVEL (meters)
Pond Water Volume Over Time
Pond L1
Watershed 18km²
4.4m Spillway
USED ALL SEASON BY CATTLE
USED FROM MID OCT. ON AS CATTLE CAMP
assumed levels for unmeasured periods
July 9 POND SPILLED
CATTLE PRESENT
15mm RAINFALL CATTLE PRESENT
APPROX. 60mm RAINFALL
APPROX. 80mm RAINFALL
CATTLE CAMPED
5000
4000
3000
2000
1000
4m
3m
2m
1m
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR


VOLUME (meters³)
WATERLEVEL (meters)
Figure D13.
4.1m Spillway
Pond Water Volume Over Time
Pond L2
Watershed 7km²
USED BY CATTLE ALL SEASON
assumed levels for unmeasured periods
5500
5000
4000
3000
2000
1000
4m
3m
2m
1m
66mm RAINFALL 2400m³ NET GAIN
POND SPILLED July 9
12mm RAINFALL 50m³ NET GAIN
20mm RAINFALL 450m³ NET GAIN
94mm RAINFALL 1500m³ NET GAIN
APPROX. 60mm RAINFALL
CATTLE CAMP PRESENT
15 19 23 27 1 5 9 13 17 21 25 29 2 6 10 14 18 22 26 30 3 7 11 15 19 23 27 31 5 9 13 17 21 25 29 2 6 10 14 18 22 26 30 4 8 12 16 20 24 28
JUNE JULY AUG SEPT OCT NOV DEC

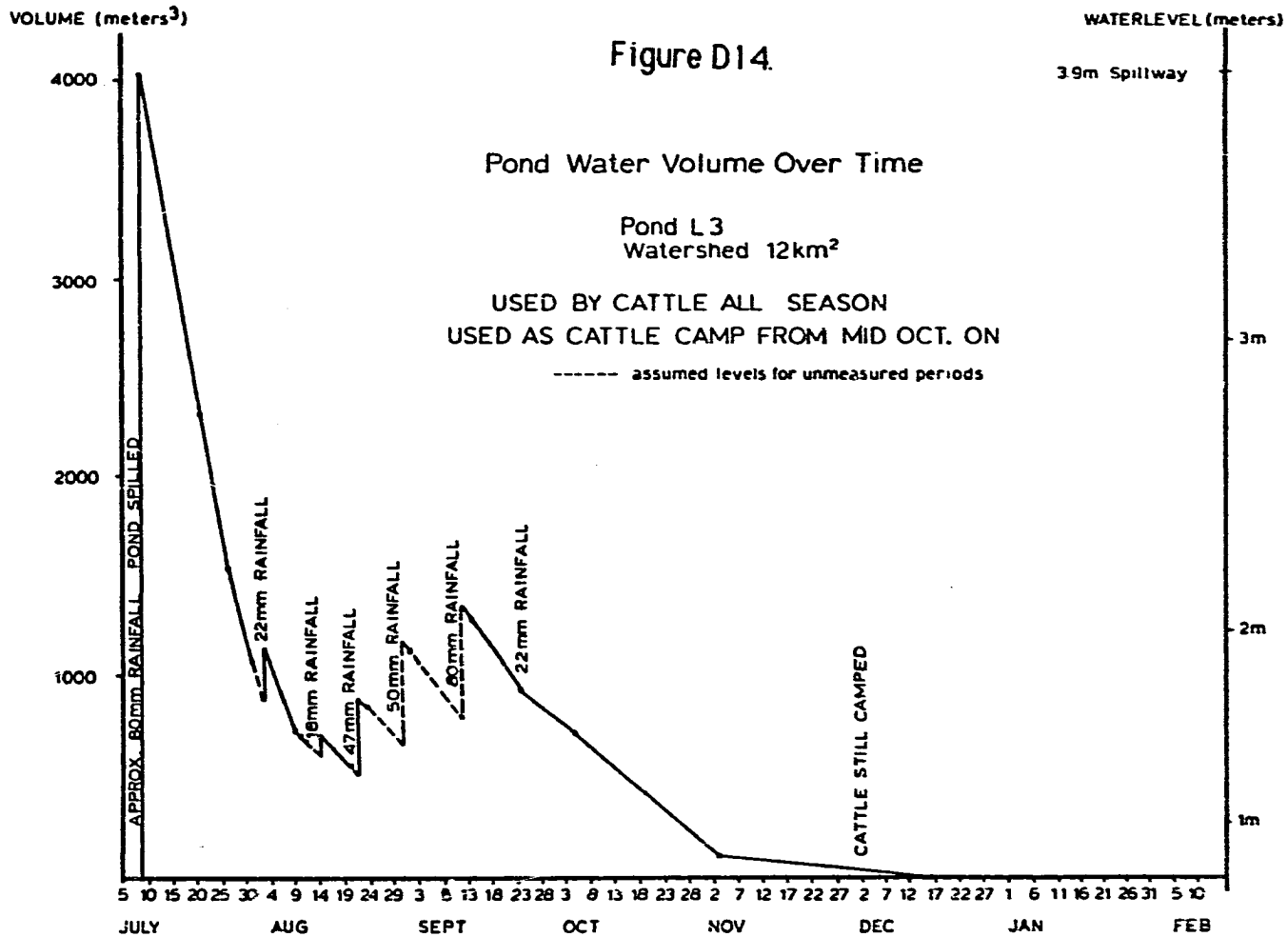


Figure D14.

Pond Water Volume Over Time

Pond L3
Watershed 12km²

USED BY CATTLE ALL SEASON
USED AS CATTLE CAMP FROM MID OCT. ON

------ assumed levels for unmeasured periods

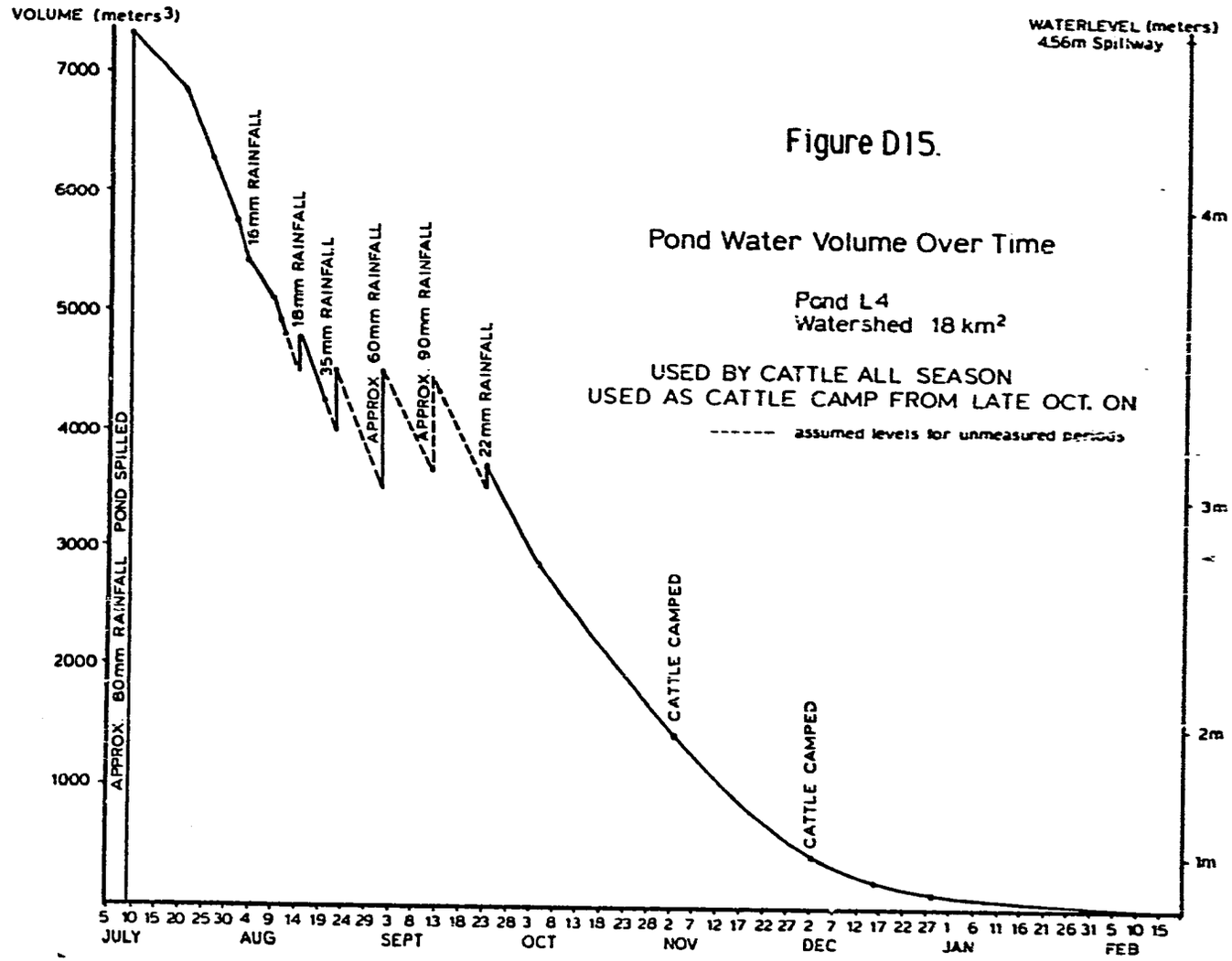


Figure D15.

Pond Water Volume Over Time

Pond L4
Watershed 18 km²

USED BY CATTLE ALL SEASON
USED AS CATTLE CAMP FROM LATE OCT. ON

------ assumed levels for unmeasured periods

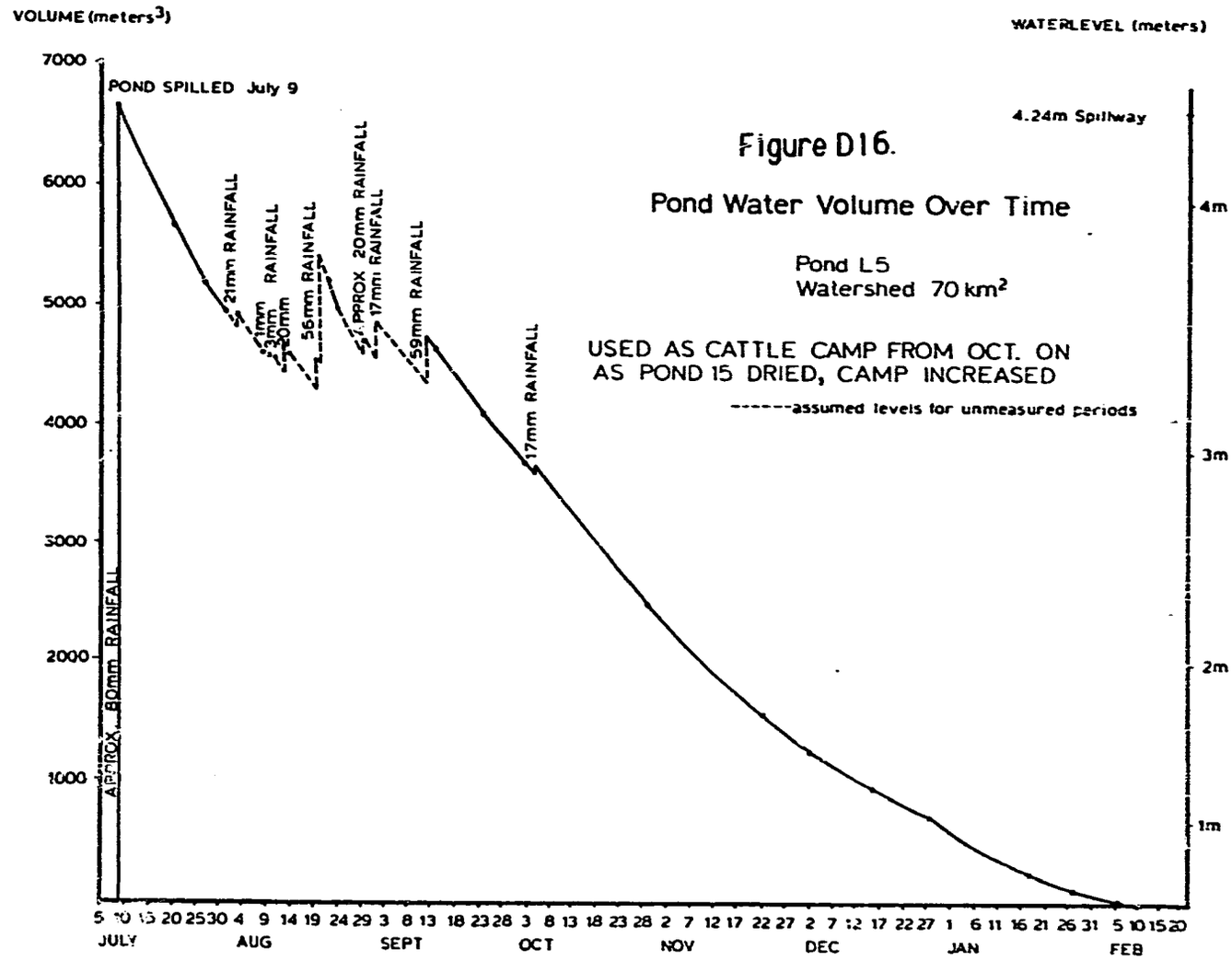
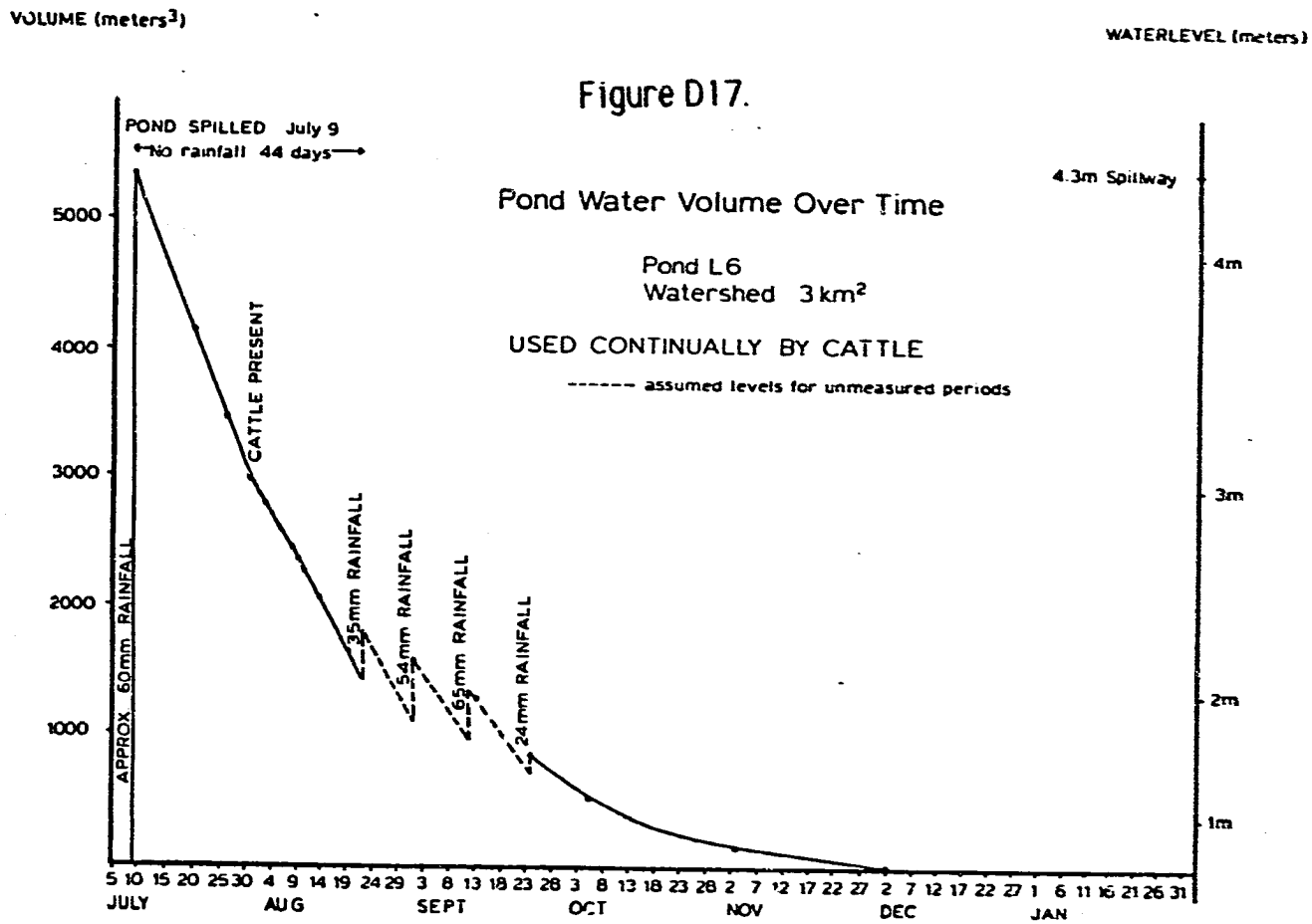


Figure D16.

Pond Water Volume Over Time

Pond L5
Watershed 70 km²

Figure D17.


VOLUME (meters3)
WATERLEVEL (meters)
Pond Water Volume Over Time
Pond L6
Watershed 3 km2
USED CONTINUALLY BY CATTLE
------ assumed levels for unmeasured periods
POND SPILLED July 9
No rainfall 44 days
APPROX. 60mm RAINFALL
CATTLE PRESENT
35mm RAINFALL
54mm RAINFALL
65mm RAINFALL
24mm RAINFALL
4.3m Spillway
5000
4000
3000
2000
1000
4m
3m
2m
1m
5 10 15 20 25 30 4 9 14 19 24 29 3 8 13 18 23 28 3 8 13 18 23 28 2 7 12 17 22 27 2 7 12 17 22 27 1 6 11 16 21 26 31
JULY
AUG
SEPT
OCT
NOV
DEC
JAN

APPENDIX E

DETERMINATION OF POND WATER LEVEL VERSUS VOLUME RELATIONSHIP

Pond water levels were periodically measured with a surveying level and rod with respect to the top of a metal rod driven into the soil adjacent to each pond. After the ponds had dried they were surveyed and a topographic map was made of each. A pond survey consisted of measuring the elevations of key points in the pond, that is points at which changes in slope occur or mark the top or bottom of the pond. Elevations were measured with respect to the metal rod. The surveying level has a scale which permits the measurement of the horizontal angle between points and triangulation (stadia) cross hairs that allow the determination of the distance from the point in question to the surveying instrument. Thus, each point for a given pond was plotted on paper and contour lines (lines of constant elevation) were drawn to complete the map. The map for Pond L6 is shown in Figure E1 as an example.

In order to determine the depth of water versus water volume relation the area within each contour line was measured with a planimeter. For Pond L6 these areas are indicated on Figure E2. The storage capacity between two contour lines was estimated by calculating the average area of the contour surfaces and multiplying by the elevation difference between them.

For the bottom section on Figure E2 the volume is calculated as follows:

$$\begin{aligned} \text{Volume} &= 1/2\ (\text{Elevation Difference})\ (\text{Top Area} + \text{Bottom Area}) \\ &= 1/2\ (0.5\text{M})\ (412\text{M}^2 + 150\text{M}^2) \\ &= 140\text{M}^3 \end{aligned}$$

Similar calculations for volumes 2, 3 and 4 yield volumes of 927, 2974 and 1307 cubic meters, respectively. Summing these volumes from the bottom to top of the pond yields a volume for each of four elevations. These are presented in the following table. These data are graphed in Figure E2 to yield a pond volume versus depth function.

Figure E2 was used in conjunction with observed pond water levels to generate the volume versus day of year graph for Pond L6. Water volumes corresponding to water depth for Pond L6.

Depth (Meters)	Volume (Cubic Meters)
0	0
0.5	140
1.8	1,067
3.7	4,041
4.3	5,348

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Figure E1. Topographic Map (Pond L6)

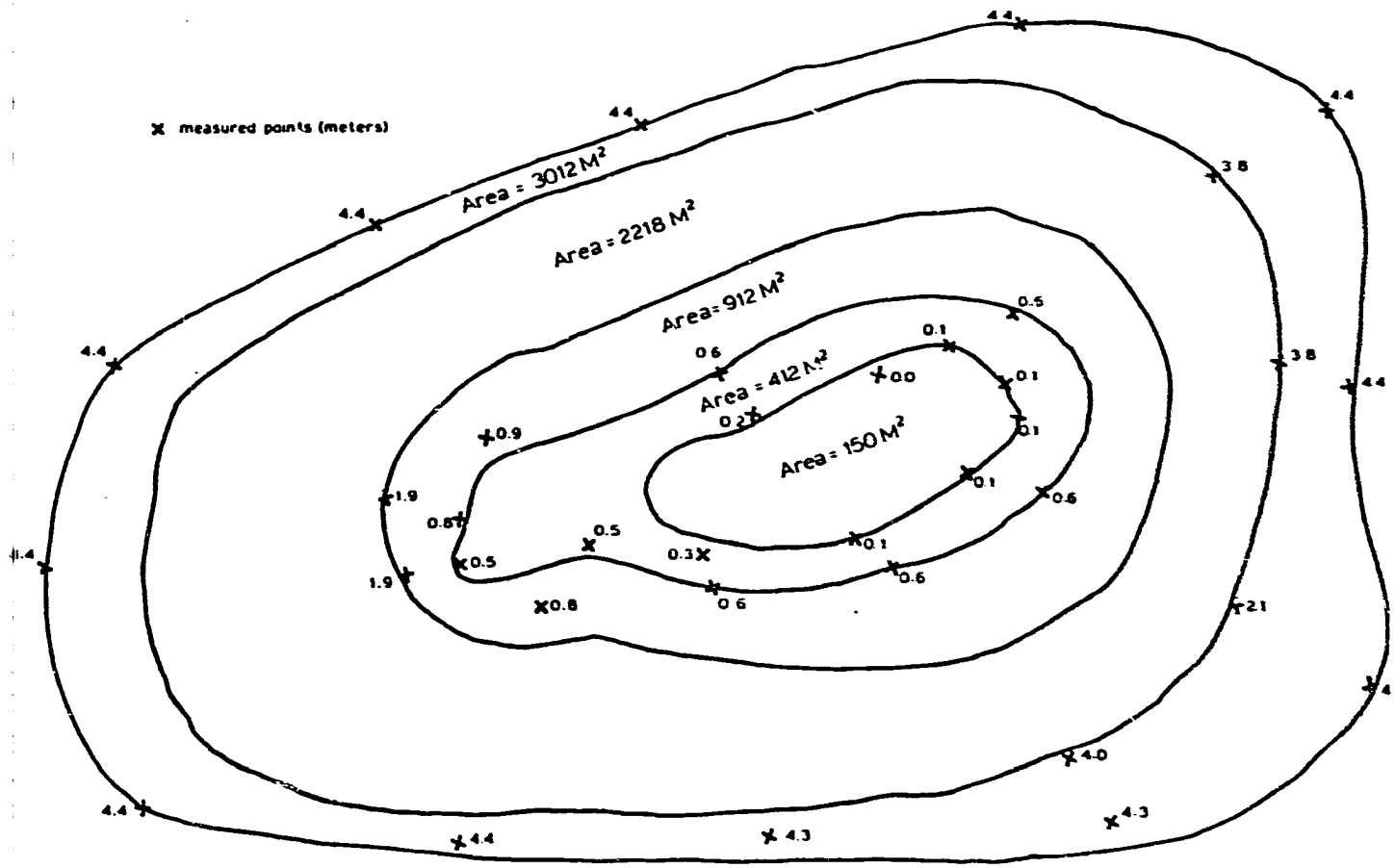
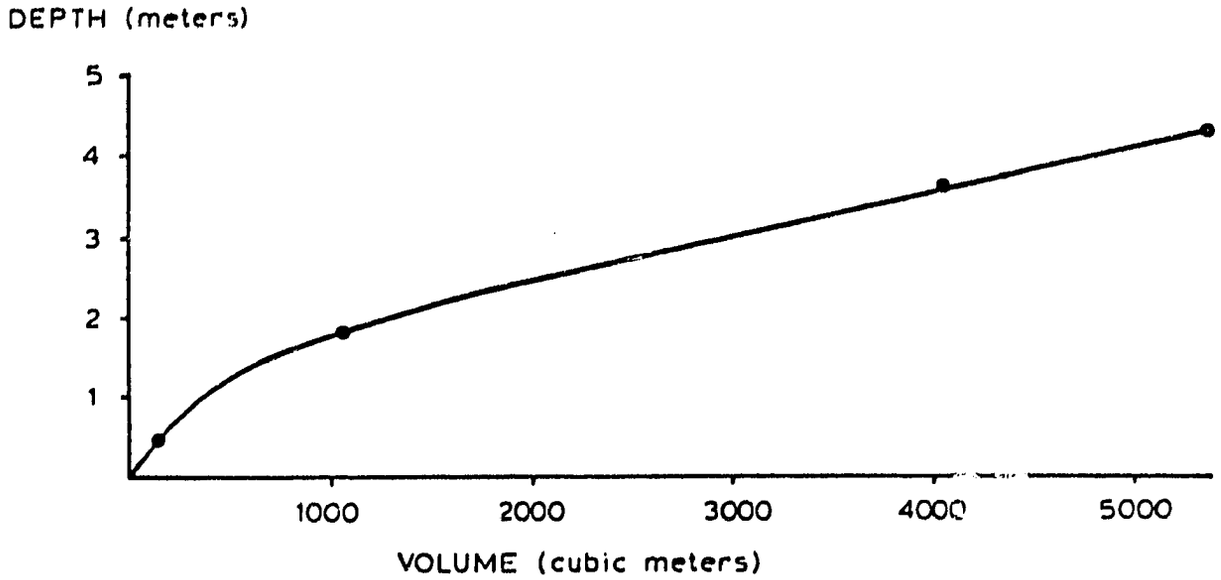


Figure E2. Pond Depth Versus Volume (Pond L6)



APPENDIX F

METHOD FOR ESTIMATING INFILTRATION AND EVAPORATION VOLUMES FOR 3 PONDS

Evaporation losses were calculated for each month using the monthly evaporation data given in Table 1.2. and multiplying the depth for each month by the average pond surface area for that month. The total evaporation and cattle consumption estimates are then subtracted from the volume of water the pond held on September 12 to yield an estimate for the infiltrated volume.

POND 10	Sept 12 - 30	Oct.	Total
Evaporation Depth (mm)	72	139	211
Average Water Surface Area (M^3)	2019	1160	
Evaporation Volume (M^3)	145	161	306

Evaporation Volume = 306 M^3 (4.8%)

Livestock Consumption = 167 M^3 (2.6%)

Infiltration Volume = $\frac{5927}{6400}$ M, (92.6%)

POND 15	Sept. 12 - 30	Oct.	Nov.	Dec.
Evaporation Depth (mm)	66	139	138	65
Average Water Surface Area (M^2)	2662	1134	400	100
Evaporation Volume (M^3)	162	157	55	7

Evaporation Volume = 381 M^3 (6%)

Livestock Consumption = 1121 M^3 (17%)

Infiltrated Volume = $\frac{4843}{6400}$ M^3 (77%)

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POND 16	Sept. 12-30	Oct.	Nov.	Dec.	Jan.	Feb.	March 1-21	Total (M^3)
Evaporation Depth (mm)	66	139	138	131	143	148	120	
Average Water Surface Area (M^2)	2260	1815	1453	1237	923	657	331	
Evaporation Volume (M^3)	149	252	201	162	132	97	40	1033

Evaporation Volume = 1033 M^3 (11%)

Livestock Consumption = 2154 M^3 (22%)

Infiltrated Volume = 6513 M^3 (67%)

9700

APPENDIX G

END OF TOUR REPORT

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INTRODUCTION

The primary work accomplished in the past 18 months was the hydrologic evaluation of the project pit-type ponds and the supervision of the construction of six new ponds by contract. The project equipment was used for the cleaning of old ponds, the completion of one pond, and the deepening of a natural pond. Firebreaks and access roads were constructed. The groundwater situation was reviewed. These activities are summarized in this report as well as observations concerning soil erosion in the area.

The most significant conclusion is that wells are a more practical source of water than ponds in areas similar to the Mbanicu zone. This is because wells offer a permanent water supply and can be constructed as well as maintained by the local population. Ponds are dry for several months each year and require outside technicians to build and maintain them.

LIVESTOCK WATERING PONDS

In terms of water resources the principal project activity has been the construction of 18 pit ponds placed in drainage channels. The work completed over the past two seasons in this area has included the construction of six new ponds by contract, the completion of one pond using project equipment, as well as the cleaning and deepening of 10 ponds including one natural pond. Ponds have been of such high priority for the project that the hydrology of 17 ponds was studied over a one-year period in order to better understand the benefits they provide to the area, and to provide more information on the optimum location and design of the ponds.

The conclusion of the pond study is that all of the ponds have severe infiltration problems. In the best ponds not more than 30% of pond water is consumed by livestock. Typically, the percentage is much less than this.

Ponds Constructed by Contract

Six ponds were constructed over a fifteen-month period by Jean Lefebvre Inc. This activity had been initiated by Mr. George Schurr, an engineer assigned to the project for several months at the end of the 1982 dry season. His recommendations were used as the basis of the contract signed in April 1983.

Pond sites were selected by evaluating individual watersheds for water-yielding potential and by using recommendations provided by the range manager on areas of underutilized range.

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The project equipment was used to construct a total of 64 kms of access road for the six ponds. Twenty-four km of the total were seven meters wide and the remainder approximately five. The project motor grader was inoperable during most of 1983 so the contractor used its own grader to smooth off the tracks cleared by the project equipment. The project grader was operable during the 1984 constuction season and performed the required road maintenance for the contractor.

The contractor worked on all six sites from April to July of 1983 but did not complete any of the ponds before rains halted construction. It was evident that the work suffered from the negligence of the contractor's construction supervisor who was rarely at the work site. The contractor returned in April of 1984 and completed the majority of the remaining work when the rains came again rendering work in the area impossible. Both the project and the contractor agreed to settle the contract at this point.

The total earth excavated from the six ponds was 44,600 cubic meters out of the anticipated 48,000. The diversion dikes were completed on all of the ponds, and mortared rock inlet structures were constructed in four ponds. On five ponds the spoils piles do not conform to the plans. It is estimated that this work will require 60 hours from the project CAT 814. The contractor was not penalized for this unfinished job, taking into consideration that the work done by the contractor in roadwork, which was the project's responsibility, represents approximately the same quantity of work.

Three of the four inlet structures washed out in the initial rains this year. It is now evident that they were undersized for the high intensity thundershowers that occur in this area. The structures were built to design specifications approved by USAID, therefore the contractor will be paid for those completed but the remaining two will not be installed.

Costs Associated with Pond Constuction by Contract

The following is a breakdown of the work done by pond and the costs for each operation.

Pond No.	Excavated Earth Cu. Meter	Protection Likes-Meters	Spillways Unit
L 1	8,000	438	-
L 2	5,600	375	-
L 3	7,200	436	1
L 4	7,800	408	1
L 5	7,800	356	1
L 6	8,200	502	1
	44,600	2,575	4

Item	Quantity	Unit	Unit Price $	Cost $
Excavation	44,600	Cu. Meters	2.81	125,326
Inlet Structure	4	Each	4,210.00	16,840
Diversion Dikes	2,575	Meters	11.54	29,484
Total				171,650

Cost of Access Road Construction

(The hourly cost of operating equipment is itemized in the cost of equipment operation section.)

24 Kms of 7 Meter Wide Road

Machine	Hours Worked	Hourly Cost $	Total $
Bulldozer CAT D-6	44	30.38	1,337
Bulldozer CAT 814	46	30.59	1,407
Grader CAT 120G	31	25.81	800

40 Kms of 3.5 - 6 Meter Wide Road

Machine	Hours Worked	Hourly Cost $	Total $
Bulldozer CAT 814	81	30.59	2,478
Grader* CAT 120G	36	25.81	929

*Contractor performed this work as well as several days of work with a bulldozer (D-7)

Total for roads = $6,951

Technical Supervision

Access Road Construction 40 Days at $235/day	$ 9,400
Pond Location and Inspection of Construction 21 Days at $235/day	$ 4,935
Total	$ 14,335

Grand Total for Six Ponds by Contract

Contractor	$171,650
Road Construction	6,951
Technical Supervision	14,335
	$192,936

(Cost per pond = $32,156)

Pond Construction by Project Equipment

The only pond construction by project equipment in the past two years was the completion of Pond 2, near Toulekedi. This job required 93 hours for the D-6 and 83 hours for the 814. Both of these times are much higher than they would have been had soil at the pond bottom not been wet, and if constant supervision had been provided for the operation.

Pond Excavation Costs

It is estimated that 400 hours of machine time (200 hours each from the D-6 and 814) are required to excavate an 8000 cubic meter pond. Using the machine costs given in the Equipment Operators section, this results in a cost of $12,000. To this amount must be added the cost of supervision (expatriate) as well as site selection. These are estimated at $15,000 bringing the total cost to $27,000. In fact the project cannot construct ponds on a timely basis because of the administrative situation discussed in the Problem Areas section.

Pond Cleaning and Deepening

Effort was devoted to the cleaning and deepening of ponds to determine the maintenance costs of ponds and to increase their potential for water storage. The spoils piles downstream from the ponds were reshaped so that most of the rain falling on them will flow away from the ponds. This is so that soil carried into the ponds will be reduced. Protection dikes were constructed around the edges of the ponds to direct water into either the upstream or downstream sides of the pond to reduce erosion on the sides of the ponds.

The removal of sediment from ponds is a job for the D-6. It is a difficult task because of the wet conditions found below a several centimeters surface layer. It was found that the most efficient method for this task is to start on one edge of the pond and excavate a trench one blade wide down to solid soil. If conditions are too wet it is necessary to move closer to the edge until reasonably solid soil conditions are encountered. The trench can then be widened in small increments, digging deeper at

times to maintain a solid base. If the work becomes unacceptably muddy, drier sediment from the sides of the pond can be pushed on top of the mud to reduce its moisture content. Attempting to begin at the middle of the pond by dozing off sediment results in a stuck bulldozer. Generally the pond bottoms are more solid on each side than the middle because ancient stream sediments tend to be deposited in the center of the drainage channels. Therefore, if sediment excavation becomes bogged down on approaching the middle from one side it may be useful to switch to the other side. At the end of each day it was efficient to spread mud out on cleaned areas to let it dry. At times the slope of one section of the side embankments needed to be reduced to allow the D-6 to push the mud out of the hole.

It was found that significantly deepening a pond is a difficult task, due in some cases to wet soil conditions and in all cases, to the need to excavate earth off the pond embankments to maintain the proper slopes. It is much more efficient to construct a slope as a pond is originally excavated than to change it after completion.

The following table contains the quantity of work performed on each pond and the time required by job and by machine to accomplish each task. The reshaping of the pond spoils piles is included in the 814 sediment removal time.

Pond Cleaning and Deepening

Pond No.	1	10	11	12	15	19	22	25
Volume Sediment(M^3)	720	727	288	910	1132	1840	910	600
Volume Deepened(M^3)	-	110	30	350	65	47	420	315
Hours For D-6 Sediment Removal	35	80	13	33	25	67	35	32
Hours For 814 Sediment Removal	21	50	10	31	24	65	25	33
Hours For D-6 Deepening	-	22	3	12	6	6	17	17
Hours For 814 Deepening	-	20	2	10	4	5	10	16

Natural Pond

A hole was excavated four meters deep at the bottom of Koli Mare in an effort to increase its water supply. This pond should be observed this year. If it does not hold water past the beginning of December, the hole should be refilled. The 814 could do this job in approximately one week. Clay taken in thin layers off the remainder of the pond

should be used as a top layer, should refilling be necessary. Each layer of fill would need to be compacted by the 814 in 40 cm lifts.

Pond Hydrology Study

Seventeen ponds were hydrologically monitored over a one-year period to provide a basis for evaluating pond performance. The most important conclusion of the study is that between 70 and 90 percent of water remaining in the ponds at the end of the rainy season is lost through infiltration, leaving little for livestock consumption.

Improvement of this problem by sealing the ponds with plastic, asphalt or clay linings would be costly and require annual maintenance that would not be performed without the supervision of a outside technician. Various possibilities for ameliorating the ponds are discussed in the report but an acceptable solution was not found.

FIREBREAKS AND ACCESS ROADS

The access roads for the new ponds have been discussed in the previous section. The 814 spent approximately 135 hours upgrading 100 kms of paths in the Ololdou and Sintiou Fissa Zones to the point where a pickup can use them. This has greatly facilitated travel in these areas.

The 814 cleaned 160 kms of firebreaks after the last rainy season, before the bush fires began. The 814 worked approximately 175 hours to accomplish this job. Normally the motor grader would do this work but it was impossible for it to work at the time.

Unfortunately this work did not prevent large land areas from being burned. It is a tradition to set fires each year after the rainy season. The fires are not extinguished by the people unless they threaten a village. Firebreaks are intended to be part of a total fire control program including fire brigades to extinguish fires. Because there are no efforts in these areas and fires usually jump the firebreaks, the fire control program is of limited value. It will continue to be so unless the people are effectively integrated into the program and decide to quit setting fires.

EQUIPMENT OPERATORS

The work goals for the heavy equipment were accomplished despite the death of the motor grader operator. During the past work season it became obvious that the equipment operators require constant supervision if they are to work efficiently. For

example, without supervision the maximum number of hours worked by a machine in a day was six; with supervision it was common to work more than seven.

The majority of equipment work was the excavation and cleaning of ponds with the CAT 814 wheel dozer and the CAT D-6 bulldozer. It was difficult for the two machines to be efficient because the operator of the D-6 would not work as part of the team. The D-6 operator also became very irritable under the constant supervision necessary to assure maximum productivity. The 814 operator was cooperative but did not follow instructions well and lacked the ability to make sound decisions when working conditions changed. He therefore required constant guidance.

These problems were resolved by the transfer of the D-6 operator to the motor grader which was only required on a part-time basis and by providing full time supervision on the work site. The apprentice of the 814 operator, who recently received his operator's permit, was assigned to the D-6. It was then possible to double the production rate previously realized.

The conclusion is that the heavy equipment operators need constant supervision. It is conceivable that a system of monetary reward for attaining well-defined production goals would increase work output, but close supervision would still be necessary to assure high quality work.

PROBLEM AREAS

Over the life of the project there have been recurring problems that have rendered heavy equipment operations extremely inefficient and necessitated the construction of six ponds by contract. The basis of these problems is the cumbersome nature of working through government agencies which usually involves many more people in even small transactions than private companies alone with the constraint of many more regulations. Therefore the operation of heavy equipment even with the presence of a competent supervisor is inefficient at best.

Operational needs such as fuel, spare parts and equipment repair have been difficult to obtain. The fuel problem was solved when USAID initiated the policy of giving fuel coupons directly to the CRED team, bypassing the Senegalese government. Spare parts usually had to be purchased by technical advisors because procurement by the Senegalese government took weeks or was never accomplished. In every case however, the money was reimbursed. When a serious breakdown occurred with the motor grader, it took weeks before a mechanic arrived on the site.

A further problem is that the equipment operators may not be paid overtime by the government. To do so would mean that they would earn more than their superiors. Thus, if work falls behind schedule it is impossible to catch up by working overtime. This is unheard of in private enterprise where contract deadlines make overtime a regular occurrence.

Finally, there is no financial motivation for a government operation to accomplish a given quantity of work. This is the underlying reason why equipment is efficiently operated by contractors but not by the government. Thus, as mentioned before, having competent construction supervisors on the job site cannot ensure efficient use of the machines in a government operation.

EQUIPMENT MAINTENANCE AND REPAIR

At this time (July 1984) the equipment is in need of a substantial quantity of minor repairs and maintenance operations. Many of these operations should have been performed months ago but were not because only the essential maintenance and repair are accomplished during the working season. These repairs require two trips by the mechanic from Manutention Africaine, the Dakar Caterpillar dealer. The first trip will require the disassembly of the machines to determine what new parts are needed and if any reconditioning needs to be performed in Dakar. The second trip will be to perform final assembly and maintenance operations. At least one barrel each of hydraulic oil (*10), motor oil (*40), and gear oil (*90) should be on hand at Mbaniou before the arrival of the mechanic.

The following is a list by machine of the minimum operations that need to be performed:

Bulldozer D-6

Replace radiator fan bearing and check shaft for wear.
Replace blade control linkage arm bearing.

Bulldozer 814

Repair hydraulic steerage system. This may include the replacement of the hydraulic pump and the replacement of seals in the hydraulic cylinders.
Repair inoperable left rear brake.
Replace radiator fan bearing and check shaft for wear.

Motorgrader 120G

Correct wobble in fan belt drive pulley.
Check fan belt and shaft for wear.
Replace blade cutting edges.
Adjust blade circle clearances.
Several new tires and inner tubes are needed.

Massey Ferguson Tractor

Two rear tires are needed.

Fuel Trailer

Two rear springs are needed. The old ones are completely broken.

For all three pieces of CAT equipment the annual service procedures need to be performed as specified in the service manuals. It is evident that the CAT mechanic has not accomplished all the specified operations in the past. Some of the required operations are valve lash adjustment, cooling system flushing with cooling system inhibitor added to the water after flushing, along with the changing of transmission and hydraulic oil where required.

The project should also procure more air, fuel, and oil filters for all the machines if they are to be further operated. Attempts to have the project procure these items have failed so stocks are very low, or nonexistent.

EQUIPMENT OPERATING COSTS

These costs have been estimated by observation of equipment operation and discussions with project personnel:

Bulldozer CAT D-6	Price = $75,000
Bulldozer CAT 814	Price = $67,000
Motor grader CAT 120G	Price = $40,000

Hourly Operation Costs

Machine	Amortization[a]	Fuel and[b] Lubricants	Operator[c] Costs	Repair and Maintenance	Total
CAT D-6	$7.50	$6.03	$1.85	$15.00	$30.38
CAT 814	6.70	8.79	1.85	13.25	30.59
CAT 120G	4.60	7.03	1.85	12.33	25.81

NOTES: [a]Based on 10,000 hours of machine life.
[b]Includes price of transporting lubricants to the job site.
[c]Includes $0.35 per hour for transport to and from the job site.

WATER WELLS

Water from wells is relied upon throughout the project area for both human and livestock consumption particularly during that portion of the year when no surface water supplies are available. The project area may be divided into two different sections for the purpose of discussing groundwater. The basic split is between the Senegal and the Gambia River Basins. The boundary between the two is clearly defined by a lateritic outcropping that bisects the entire project area.

The Senegal River Basin

In this area groundwater is principally found in or above rock, usually schist. There seems to exist little possibility for high-yielding water wells in this area. The immediate prognosis for the area is to deepen existing wells that already yield some water in an attempt to increase the supply.

The exceptions in this area are in the vicinities of Gabou and Ololdou. In these two regions good wells exist apparently owing to the existence of faults which feed water into the two areas. Both the regions are basin bottoms surrounded by hills which contribute to the flow of water.

In the long-term, if further groundwater development is to be realized in this zone, extensive geologic studies will be required to determine where deep small bore wells need to be placed to intercept deep rock fractures that may contain water. Low flow rates from existing small bore wells in the area (Kahé and Sintiou Fissa) suggest that deep wells would suffice only for village supplies, not for large numbers of livestock.

The villages in the Sintiou Fissa Zone which are along the dividing line between the two river basins all have wells on the continental terminal (west) side of the lateritic outcropping. Although these wells are not as good as wells in the Mbaniou Zone, they seem to have more potential than those east of the escarpment.

The recommendation for a short-term intervention in the Ololdou and Sintiou Fissa Zones is to deepen wells at the following villages:

- Sira Mamadou Bocar, Samba Kontaye, Sira Dundee.
- Arigabo, Feté Golombi, Ourousoulé, Gambi Diaobé.

These are all villages that have marginal wells that could possibly be improved by deepening. The potential for water resource development in this area seems low. The

present system of migration during the dry season from those villages with poor wells continues to be the most realistic strategy. Senegal is fortunate in that there are substantial groundwater resources throughout most parts of the country. It would not be advisable to expend large sums of money developing this marginal water supply.

The Gambia River Basin

The area in the Gambia River Basin is geologically referred to as continental terminal. It consists of ocean deposited sediments overlying bedrock. Throughout the Mbaniou Zone there is a sandy layer beginning at a depth of between 30 and 40 meters that contains significant quantities of water. This layer is sometimes broken by layers of sandstone or large rock fragments, but generally seems to yield more water the deeper it is penetrated. Measurements over the past several years by FAO hydrologist, Piere Curetti, indicate little or no drop in the water table elevation. Thus, there seems to be a reasonable water supply in the aquifer.

Local Wells

Most of the wells in the Mbaniou Zone have been constructed by local well diggers. These are large bore wells, usually about 1.8 meters in diameter that are plastered with concrete over wire netting and reinforcing rod above the water level. Below the water table, pipe sections that have been fabricated on the surface are sunk into the water-bearing strata.

The two causes of failures in these wells are insufficient penetration of the aquifer and the collapse of the prefabricated pipe sections. Although the concrete plaster flakes off the sides of many wells this does not seem to seriously impare the wells' utility. It is an arduous task to dig the pipe sections one meter below the water table but once this is accomplished an adequate water source for a village is established.

The more serious problem with these locally constructed wells is the tendency for the concrete pipe sections to collapse at the bottom of the well. This is because they are too thin, the concrete is of questionable quality, and too little reinforcing steel is used. When these sections are placed into a well, they remain intact for a year or more while the earth settles around them resulting in increasing stress. After several years a critical stress is attained at which point the concrete sections are crushed.

Given that the well failures occur because of these pipe failures, improvements should be made so that the concrete pipe walls are sufficiently thick (10 cm), the concrete is of good quality and adequate reinforcement steel is provided. These sections need to be fabricated at the bottom of the well unless a motor-driven winch with a tripod is available.

The book, La Construction des Puits en Afrique Tropicale (Burgeap, 1981), provides excellent designs and instructions for well construction of this type. Local well diggers can be trained in this type of construction. This would require a long-term program to assure that quality work was performed.

A 40 meter deep, locally built well would cost approximately $7,000. This includes $3,000 for labor, $3,000 for materials (cement, reinforcing rod, forms, tools) and $1,000 for technical assistance.

Well Construction By Contract

Given that the project has surplus funding it would be most effective to use it for wells in the Mbaniou Zone. Considering the short time period available, the work would have to be done by contract. Unfortunately most of the wells in the zone would not be safe to deepen with the equipment used by contractors. Therefore, it would be necessary to dig mostly new wells.

These wells cost approximately $23,000 each according to estimates supplied by the Project Director. In order to assure quality construction, the contractor's work would need to be inspected by the USAID Engineer or another recognized wells authority such as Piere Curetti. The wells should penetrate the aquifer by 5 meters to assure a long lasting supply of water.

It has been suggested that the construction of good wells in the villages of the Mbaniou Zone would increase grazing pressure around the villages. The opposite may be true because at present the cattle spend much of the dry season waiting in the villages to be watered at the wells. This is because flow rates into the wells are so low, cattle watering becomes an all-day operation. With a good well they could be quickly watered and herded to outlying areas where forage is more abundant.

There are two large bore wells in the area that were built by technical equipment that need repairing. These are at Boulel and Gourel Macumbé. It appears that both will need to have pipe sections at the bottoms of the wells replaced due to clogged filters. Since the upper casings of the wells are solid, reinforced concrete, they may safely be repaired by contract.

It may be possible to deepen wells at Sowol and Ndiakone by contract. All the others may be too dangerous to work in with jack hammers. The villages that seem to have the most need for new wells at present are, in order of priority:

- Garalla, Toulekedi, Velingara, Diare Maboubé,
- Ndiya, Diare Mbolo, Medina, Guiraye, Gonadé.

Mbaniou presents a special problem because it is located near the project station which has an excellent well. The project should consider letting the village use that well for cattle, and charging the village for the fuel required to pump the water they use. Building a new well in Mbaniou does not seem reasonable given the existence of a good one 500 meters away, even though the village is denied access to it. An alternative would be to deepen the village well using the methods described in the Local Wells section.

WELLS VERSUS PONDS

There is continued controversy in Senegal concerning the merits of wells versus those of ponds for water supply in areas where livestock is raised. The present discussion applies only to the continental terminal region in Senegal where a good groundwater resource exists. This area encompasses most of the country.

The main arguments favoring ponds are, they tend to spread out grazing patterns (if constructed in underutilized rangeland), and they require no energy to water livestock. Wells are built near villages where livestock tends to overgraze and they require large quantities of energy to lift water.

The major advantages of wells are that they may be constructed using methods familiar as well as available to local people, and they provide a year-round water source. Ponds need to be constructed with heavy equipment by outsiders and are dry for several months each year.

The contracted prices for ponds and wells are of the same order of magnitude, approximately $30,000 and $23,000 respectively. After completion, a pond should be maintained with heavy equipment every five to ten years. A sound well constructed by contract will last indefinitely with the only maintenance being periodic cleaning that can be accomplished with hand tools by villagers.

Wells can be and are constructed by villages as previously discussed. The main problem is that the construction techniques need to be upgraded to prevent the collapse of the well bottoms. Building solid wells using local workers would cost on the order of $7,000 per well and inject money into the local economy if paid for by donors. USAID is currently financing a well construction project in the Casamance Region of Senegal (which is also training local people to construct sound water wells without outside assistance). This is an example that should be given consideration throughout Senegal.

In summary, although ponds spread out grazing pressure, they do not provide a year-round water supply; they are constructed and maintained with methods unsuitable to and beyond the means of the outlying areas of Senegal. It is therefore recommended that

in areas such as the Mbaniou Zone efforts be concentrated on improving well construction techniques in order to provide continuous water sources which can be built and maintained by local people.

SOIL EROSION

Soil erosion is of concern in the project area because it reduces the productivity of both agricultural fields and rangeland. Particularly in the vicinity of villages there exist large areas of denuded terrain. These areas must be a result in part of overgrazing and, in some instances, of the effects of cultivation. The result is the same; the surface loamy soil has been removed by wind and water leaving a more clayey, less erodible subsoil that does not provide a medium conducive to plant growth.

The range manager has performed several field demonstrations illustrating techniques for reclaiming denuded areas. The primary benefit of these plots has been to sensitize the local population to the problem of land degradation, and to the monumental task of its revegetation. The message is that the main component of a range conservation program needs to be the protection of productive land, primarily by controlling livestock usage.

If structural measures are to be used they can only be justified in conjunction with agricultural fields; it is in these areas that the most economically significant erosion is occurring. There are frequent instances where denuded areas are encroaching into fields. Soil is transported from the fields over the bare areas into drainage channels. Several measures that should be considered to control this soil loss include contour plowing, gully erosion control with simple rock walls and vegetation, and planting trees on the downslope edges of fields to anchor the soil.

CONCLUSION

The primary function of the CRED team was to evaluate the benefits from the project. In terms of water resources, pond construction has been the major intervention. As a result of the hydrologic study, estimates of the amount of additional water furnished to livestock by the ponds would average under 1000 cubic meters per pond, which is less than half that anticipated in the project design. This problem is a result of infiltration losses which would be cost-prohibitive to stop.

A major problem in the construction of ponds is heavy equipment operation. The economic analysis should use the costs for the contracted ponds because it has been demonstrated that the project cannot efficiently construct ponds. The new ponds were constructed on a contractual basis for that reason.

In the Mbaniou Zone, upgrading the capabilities of the local well diggers to construct sound water wells seems to be the most desirable means of improving the water supply. The construction of wells by contract is appropriate if large amounts of funding are available. Over time, working on the local level would be less costly and provide for more local participation. At present the attitude of waiting for gifts from the project is too prevalent.

This type of wells program could work over much of Senegal where substantial groundwater reserves exist. Water supplies are much more limited in the Sintiou Fissa and Ololdou Zones. It would not be appropriate to make large investments in these areas without further studies.

Given that the project has heavy equipment, its best use is enlarging paths to provide access to remote villages. Firebreaks will not prove effective unless the number of fires set is greatly reduced and those that do start are extinguished quickly. The old adage still applies that if people want to burn the bush they surely can and will.

Future projects in areas such as these should begin slowly, testing methods and confirming results before making large commitments. If possible methods that can be learned by the local population should be employed to ensure a permanent benefit.

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Eastern Senegal Range and Livestock Development Project

Socioeconomic Study

Henri P. Josserand and Patrick Thomas

Prepared by
Center for Research on Economic Development
University of Michigan

for
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Contract No. 685-0202-C-00-2137-00

February 1985

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EASTERN SENEGAL RANGE AND LIVESTOCK DEVELOPMENT PROJECT

SOCIOECONOMIC STUDY

by

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I. PROJECT BACKGROUND AND SETTING

I.1. EXECUTIVE SUMMARY

This is one of four reports by the Center for Research on Economic Development at the University of Michigan on the monitoring and evaluation of the Eastern Senegal Range and Livestock Development Project No. 685-0202-C-00-2137-00. The project was identified at a time when Senegal was trying to rebuild its national livestock herd and bring itself closer to food self-sufficiency in basic staples. Senegal lost most of its cattle in 1972 and ensuing years. Although the national herd was eventually brought back up to predrought level (in 1979), the mid-seventies saw an ongoing struggle to rebuild herds on the basis of still very limited range resources. According to the Project Paper for the period of September 29, 1975 through December 31, 1978, the purpose was "to insure that the population involved in the project are prepared both to manage and maintain the improved system, as well as to use the increased revenues from that system to improve their conditions of living." The basic idea was to design a replicable, integrated approach to range maintenance and livestock development. This was done through a technical package comprising original and experimental components, especially the establishment of water catchment ponds scattered through vast areas of previously underutilized rangeland. Unfortunately, the baseline and monitoring data necessary to assess the applicability and replicability of the project's experimental components were not systematically collected. In 1980, the project was therefore redesigned to include monitoring and evaluation for the assessment of project impact, viability and replicability, and the design of a range and cattle management plan.

The assessment and monitoring effort undertaken by the CRED team and project staff included hydrology and engineering, range resources and use (plus the design of a suitable range management plan), and socioeconomic indicators.

Chief areas of the socioeconomic survey covered demography and extent of out-migration, agriculture (including area cultivated and production by crop), labor, sales, and income. Household food consumption was also monitored throughout the year; livestock was monitored for size and composition of herds, role in agriculture, and income. The study of sociocultural stratification, the importance of livestock, change and effects of out-migration was undertaken also. Finally, nonfarm income (both locally earned and remittances) as well as the impacts of project interventions on animal health, marketing, extension, education and human health were assessed.

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The principal findings of the socioeconomic survey can be summarized briefly as follows:

- The importance of agriculture in the rural economy, and its strong complementarities with livestock had not been fully appreciated in the project documents and in the orientation of overall project activities. This was seen first and foremost as a range management and "livestock" project, whereas the beneficiary population, although it derives most of its income from livestock sales, consists essentially of sedentarized farmers.

- The extent of out-migration and its impact on the local labor force had been underestimated; consequently, the role played by migrants' remittances in rural incomes as a source of investment, and motor of social change, is much greater than was previously suspected.

- The impacts of project activities have been quite mixed and felt in many ways. Some interventions, like firebreaks, have been ineffectual with respect to their primary purpose, but have had some sizeable positive secondary effects. For example, firebreaks and construction access roads have opened up a large area which seriously suffered from isolation from the rest of Senegal, and from lack of communications within the area itself. The water catchment ponds built throughout the project area have collected water, and have definitely been used by animals, but their impact is severely limited for a number of reasons. First, the style and practices of livestock and range management prevalent in the area are not reconciled with the rationale behind the location of most ponds. People still prefer having the ponds close to their villages. Secondly, the design of ponds -- given local soils -- leads to extremely high water losses through infiltration. Ponds therefore only retain water for short periods of time, and any gains to the animals or relief on denuded areas around villages are not sufficient to reverse established trends in livestock weights or in the condition of the range near settlements.

- On the other hand, some ancillary project interventions have given very encouraging results. The restructuring of extension for animal health services along rather experimental lines, in the Senegalese context, is a notable example. Cattle marketing and supplemental feeding also made some inroads, although much remains to be done in these areas. Still with respect to extension services, the well-attended and successful functional literacy program in Pulaar has contributed to opening the area to the outside world, and in revitalizing the structure of social relations between sexes and between social strata. Finally, some infrastructural developments have provided the essential basis for the appearance of additional social services. For instance, the Mbaniou base has become a pole of attraction for public services in education and human health. Similarly, the local Maison Familiale Rurale introduced infant weight and growth monitoring, and motorized grain mills.

- The nonagricultural sector is surprisingly and increasingly active. Trade has opened up; migrants' remittances fuel economic exchanges and provide the main nongovernmental source of funds for private and community level investments.

- For these and other reasons, the social system, while remaining highly stratified and tradition-oriented, shows definite signs of change. However, the social

system is also going to place some limits on the adoption of new practices in farm and livestock/range management. For one thing, the secular pattern of long-distance migration is likely to remain a major feature in the area, with known implications on availability of family labor, consumption and investment from remittances. The low level of education and strongly hierarchic decision making will continue to constitute serious obstacles to the adoption of new ideas and methods on livestock and range management, and on protection of land around villages. Finally, some dynamism has been observed in social stratification, but it remains strong; in conjunction with fractionalism in the area, it most likely will continue to resist communal resource management schemes. This resistance can eventually only be overcome by forces applied from within the local society, after very long-term sensitization and education efforts.

1.2. INTRODUCTION AND BACKGROUND

This is one of four reports reporting on the monitoring and impact assessment effort for the Eastern Senegal Range and Livestock Project, hereafter known as the Bakel project, as amended. The other reports include: Synthesis (of findings), Range Management, and Soils and Water Engineering.

The purpose of the original project (December 1974), was to finance the cost of the equipment, materials, construction, technical assistance, education, training and research aimed at improving livestock production in the Toulekedi/Sarre Zone. The project was to provide a model for an integrated approach to livestock development which might be expanded to other parts of Senegal and the Sahel. The main components of the Logical Framework were as follows:

- Project Purpose: To develop a replicable system of integrated stock and range management socially acceptable and economically viable.
- Verifiable Indicators: Existence of range and stock, increased target area incomes, GOS capability to manage the system.
- Means of Verification: "Proper" use of water-points, improved range conditions, improved milk production, cattle numbers under a proper ceiling, offtake rate up to 14%.
- Necessary Assumptions: Support by the Government. No unusual constraints on production (e.g. weather), Nonuniqueness of the Bakel area.
- Project Expected Output: Introduction of the concept of range and of livestock management, management capability demonstration, training, research.

This type of project was given high priority by the Government because of their willingness to get over the drought, their sectoral objective of rangeland control and development, and the new emphasis placed on that area of the country. The project itself

was to follow a systems approach encompassing livestock, vegetation and water resources, human needs, transportation and marketing. The easternmost part of the country, known as Senegal-Oriental was seen as "zone de naissage;" young animals born in the area were to grow out in the peanut-growing areas of central and western Senegal.

The original project was evaluated during the Joint Assessment of AID Assistance to Senegal, in 1980. As far as we are concerned, the results of the evaluation showed that the model sought had not been provided, mostly due to shortcomings in research and monitoring efforts.

In addition to an expansion and organization of the project area into three distinct zones (see Map 1.1), the project paper amendment identified four main types of tasks as part of the redesign effort: (a) to refine the application of the ponds to the specific range; (b) to introduce range condition monitoring and managing techniques; (c) to refine certain health and management services; and (d) to refine project management according to this set of goals.

With particular respect to monitoring and evaluation there were two main objectives:

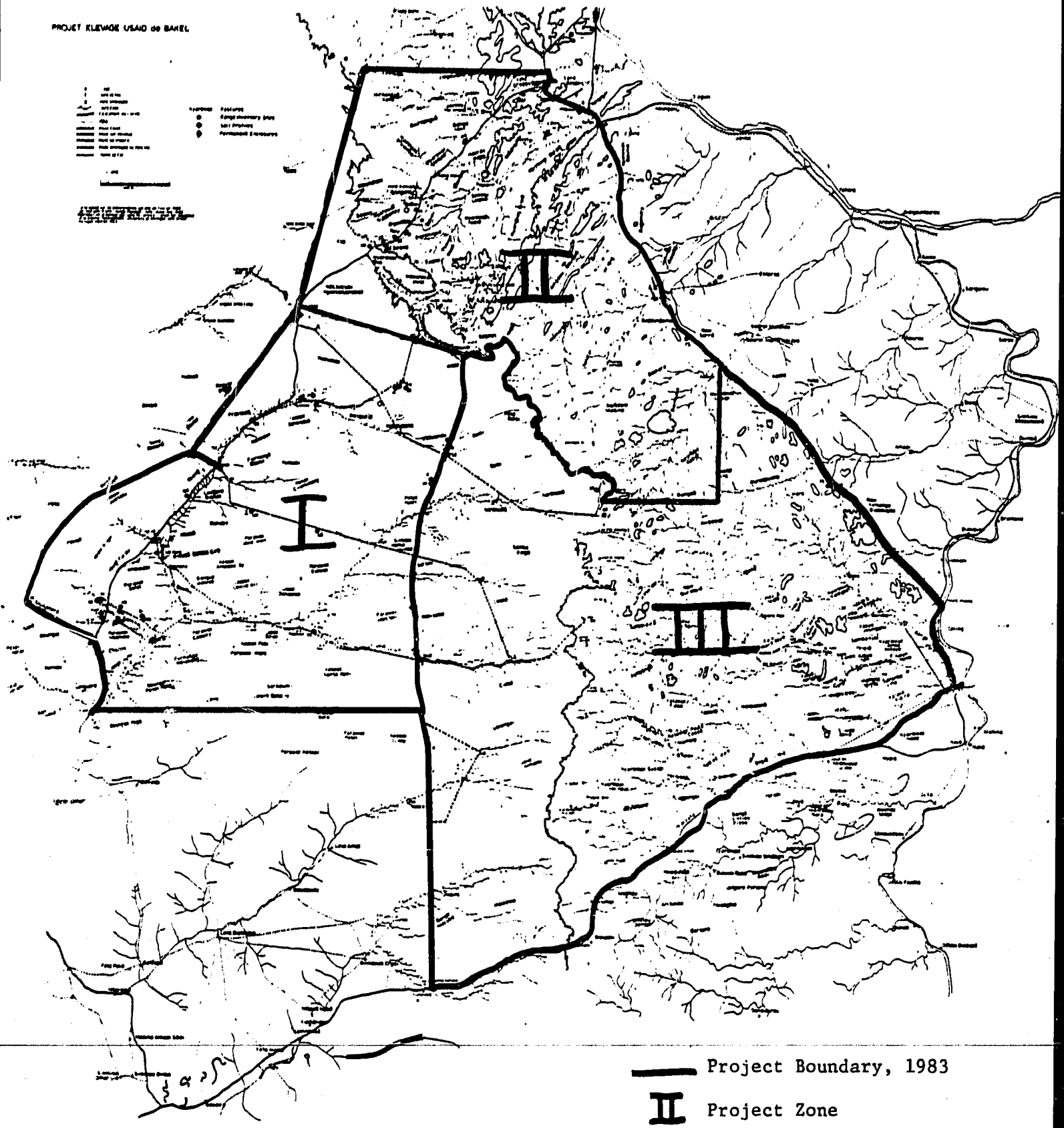
i. To assess the net effect of project interventions to determine the economic viability and potential for continuation in the same area or replication elsewhere (this addressed essentially questions of hydrology and engineering, and socioeconomic issues);

ii. To use the information to concurrently regulate animal numbers to range carrying capacity and water supply, that is, to design and test a Range Management Plan.

1.3. RESEARCH APPROACH

The socioeconomic study started in January of 1983, and was carried out in the project's three zones: Mbaniou, Ololdou and Sinthiou Fissa. Some baseline data had been collected during earlier phases of the project, but it covered only a few specific areas, focussed on part of the project zones only, and was incomplete. Without the option of doing straightforward before/after comparisons, the best approach was to gain as clear an understanding as possible of the overall situation in the area, and a much sharper appreciation for specific constraints to development. The information collected during the socioeconomic study therefore covered the domains most likely to provide a better understanding of the socioeconomic, cultural and physical milieus. The various areas of enquiry were covered through interviews and surveys in 120 households in a dozen of villages; they were as follows:

Map 1.1. Map of the Project Area as of 1982



- Human Demography: household composition, including primary and secondary occupations, level of education, and migration experience. The basic demography of other village households were also collected.

- Agricultural and Livestock Calendars: once, for all surveyed households, including typical activities in agriculture and animal husbandry, by crop and season.

- Field Surveys: measurements of all fields of all surveyed households, and information on crops cultivated, fallow, and production.

- Food Consumption: each of the 120 surveyed households was followed for three consecutive days, at three different seasons of the year. Type and quantity of food prepared, and the number of consumers, including pregnant and nursing women were recorded.

- Sales of Farm Products: for all households, every two weeks, recorded sales of crop and livestock products, including milk. This included quantity sold, type of buyer, and price received.

- Purchases of Food Items: for all households, semimonthly questionnaires were administered on purchases of food items, including quantity, price and place of purchase.

- Health Status and Demographic Change over the Survey Period: semimonthly interviews for each followed household.

- Evolution of Livestock Holdings: semimonthly interviews on changes in holdings of large and small ruminants (births, deaths, purchases, sales, loans, etc.).

- Agricultural Labor Allocation: 30 households were interviewed daily for 120 days. Information covered time spent by family and others in the household's fields, and their activities.

- Life Histories of Cows: life histories for 402 cows, including age, number of offspring, their outcome, data on survivors, etc.

- Livestock Census: a one-time census of livestock holdings of all surveyed households.

- Nonagricultural Income: unscheduled interviews of all surveyed households, including activity, season, and estimated revenue.

- Manure/Yields Relationship: measurements of manure applications before planting and of yield, for a small sample of fields in the area.

- Infant Mortality: for all surveyed households, pregnancy histories of women, number of miscarriages, infant deaths, etc.

- Migration: unscheduled interviews in all households on the number of years abroad, location, status and place of employment, and current situation.

Livestock plays a pervading role in people's social and economic lives, and one had to integrate the social system into resource management plans. Some of the information

collected by the socioeconomic team was therefore put to several uses. For instance, the range management plan used data collected by the socioeconomic team on herd composition, livestock marketing, herd size per household, field sizes and yields, and labor allocation to herding tasks. The socioeconomic data used for degradation control included labor allocation, and overall household economy. With respect to herders' associations, it covered herd size and composition, migration, village affinities and other anthropological insights. Finally, for livestock productivity, the socioeconomic team collected information on milk production, and the place of milk in human consumption.

Gathering information over the three project zones involved a combination of data collection approaches and processes. In addition to the principal field researcher, several teams of part-time or full-time enumerators were required. The chief ones were as follows:

- AVEs (Agents Vulgarisateurs d'Elevage) and ATEs (Agents Techniques d'Elevage): project extension staff who worked part-time on the survey from the villages where they were assigned.
- Women Enumerators: hired and trained separately, they worked full-time throughout the study on food consumption in the three zones; they were also residing in their assigned villages.
- Specific Surveys: small teams who were employed full-time for short periods, working on specific areas (measuring fields, tracking labor allocation, collecting cattle life histories).
- The Principal Field Researcher: worked full-time supervising all surveys, and conducted unscheduled studies on social organization, village histories, migration and remittances, nonagricultural income, etc.
- Two Assistant-Researchers: one supervised enumerators and conducted specific surveys; the other verified data and entered it into the portable microcomputer based in Mbaniou. This computer (Hewlett-Packard 85) was operating on batteries powered by a combination of solar panels and occasional charges from the base's nighttime electrical generator.

1.4. THE SETTING

1.4.1. Recurrence of Subsistence Crises

A recent study of the Bakel area has documented the recurring pattern of subsistence crises that spanned an 88-year period from 1858 to 1946. According to administrative documents and oral histories of this period, there have been five major famines lasting eight months or more, three famines stretching over two agricultural seasons, nineteen

famines lasting three to eight months, and twelve periods of hardship that lasted about two months each (Chastanet, 1982:29).

This does not directly apply to the project area since only the northern section of the Ololdou Zone would have been included in the study and our own experience has shown that there is wide variations in rainfall patterns in the region. The fact remains, however, that the area has been plagued with a recurring pattern of subsistence crises over the last hundred years. The social structures and the economic strategies of the local population reflect this fact.

1.4.2. Historical Background

The project is located in the northeastern third of an area known as the Boundou. The Boundou as a theocratic state was established by Malick Sy in 1690 and kept in the hands of his descendants until the 1900s. The sociohistorical roots of the population in the project area today are directly linked to the establishment of the Boundou as a theocratic state. Malick Sy, a Toucouleur of Torodo priestly caste went from the Fouta Toro to the Boundou partly to convert its pagan Bambara inhabitants to Islam. The economics of the Boundou during the eighteenth and the first part of the nineteenth centuries were based on the control of gold mines along the Falémé, the control of trade routes from Mali to the Gambia, and on the production and sale of millet (Suret, no date).

The project area covers approximately 260,000 hectares. It is administratively divided into three zones: the oldest zone Mbaniou, and two new zones, designated as the Ololdou and Sinthiou Fissa Zones, which were added to the project in 1980. At its widest points the project area is approximately 100 kilometers wide by 100 kilometers long.

1.4.3. The Mbaniou Zone

Population is concentrated along two axes. There are a number of villages along the Bakel-Mbaniou-Goudiry road, and a number of villages along an east-west axis starting from Mbaniou. These villages have been linked by a project firebreak. The thirteen villages in the area are small, ranging in population from less than 100 to approximately 350 inhabitants.

1.4.4. The Sinthiou Fissa Zone

The Sinthiou Fissa Zone has by far the largest number of villages; most are 10 to 15 kilometers from the Bakel-Kidira-Goudiry road. The major villages of Bele, Sinthiou Fissa and Youpe Hamady are along the road itself, but an important line of villages are located just east of the escarpment. Some of these have major problems with water for human consumption. The villages of Wali Diala, Birfal, and Gourel Maman Ndieye are totally

abandoned during the dry season. The population of these villages migrates to the village of Ourousoulé, in the center of the zone, where there is a good well. The other villages along the eastern side of the escarpment must draw water from wells located on the escarpment, which are generally three to five kilometers away from the settlement.

1.4.5. The Ololdou Zone

The O dou Zone has two main clusters of villages. The northernmost of these consists of small villages along the Bakel-Mbaniou road between Bakel and the escarpment. There is a group of villages starting with Ololdou to the north which are fairly isolated from one another, and two important clusters of villages to the south, the Gourels and the Siras. These villages range in population from 125 to 150 or less.

The Gourels and in particular, the Siras, have a major water problem for animal and human consumption. This forces a part of their population to migrate during the dry season to find enough water for their animals. The difficulty in obtaining water in these villages stems from the geology of the area. The escarpment which is quite pronounced throughout the area marks the end of the continental terminal and the watershed boundary between the Gambia River, and the Senegal and Falémé River Basins. On the continental terminal it is possible to find groundwater at depths of 35 to 55 meters. On the other side of the continental terminal which borders the Ololdou and Sinthiou Fissa Zones, groundwater is rarely available. The closer one is to the escarpment the least likely one is to find groundwater.

The second concentration of villages of the Ololdou Zone lies along the Bakel-Kidira road where the villages of Bema and Sarre are located. The largest community in the zone is the small town of Gabou.

1.5. BASIC DATA ON PROJECT BENEFICIARIES

1.5.1. Ethnic Composition

The majority of the population in the project area considers itself Hal Pulaar of Fulani and Toucouleur descent. Along the northern and eastern boundaries of the project zone there is a group of multiethnic communities. These are the villages of Sarre, Bema and the small town of Gabou. They include Toucouleur, Fulani, Bambara and Soninke population. In a few other villages of the project zone there is a very small percentage of non-Fulani or non-Toucouleur people of undetermined caste. These small groups can be found primarily in border villages of the Ololdou and Sinthiou Fissa Zones.

The study sample reflects the rural character of the project area: villages chosen are primarily monoethnic, with strong dominance by the Toucouleur and Fulani where patronyms dominate among the upper and ruling castes of the Boundou. There are households that identify themselves as Fulbe, and the population as a whole idealizes Fulani culture and ideology, but the dominant patterns of social organization are Toucouleur.

1.5.2. Social Structure

The social organization follows the hierarchical stratified caste system of the Toucouleur, where the Torodo priestly caste holds the superior position. The Torodo were the first to convert to Islam and assumed the position of power as priests and headmen. Prior to their conversion, the Torodo were not necessarily members of the upper caste, but they consolidated their dominant position through their role as proselytes of Islam (Wane, 1969: 34-38). The Torodo caste is highly endogamous; women are closely guarded and expected to marry within the caste.

The Torodo are followed by the Sebbe caste who, prior to Islamization, had been the ruling group. Within the caste there are several levels of rulers, soldiers, courtiers, and counselors, all of whom are considered freemen. Fishermen or Subalbe are the only other freemen caste, but there are very few members of this group in the project area. After the freemen caste come the Maboubé or craftsmen; weavers, smiths, woodworkers, potters, musicians, singers and genealogists. The lowest position in the social system is held by the slave caste. The slave caste consists of all social strata of other ethnic groups subjugated by the followers of El Hadj Malick Sy, or sold by their captors to families living in the Boundou. Most Maccube or slave caste households in the area are of Bambara origin, the Bambara being the ethnic group defeated by El Hadj Malik Sy.

The general social composition of villages reflects the social organization of Toucouleur society. The typical village is dominated by the upper caste Torodo family with slave and artisanal castes under its leadership. Some villages are dominated by the Sebe, the caste of former rulers, or, as in the case of Diare M'Bolo, the name itself defines the village as being one of artisans.

The most obvious economic manifestations of the caste system appear to have receded. Artisanal and slave castes are not under direct economic obligations to the upper caste. However, social structural obligations still play a very important role in the Boundou. The maintenance of the structure of social relations according to caste hierarchy is constantly in evidence. All social relations within as well as between villages revolve around the structure of caste hierarchy. Deference is given to upper caste

members, who are expected to assume appropriate ritualistic roles, in the sacrificing and butchering of animals, for instance. Table 1.1. below shows the distribution of heads of household in the survey's sample.

TABLE 1.1.

CASTE OF HEAD OF HOUSEHOLD; ALL ZONES

Machoubé	414
Smiths	69
Peuhl	82
Torobe	278
Laobé	51
Maboubé	46
Diarrébé	18
Ceddu	146
Faddoubé	17

1.5.3. Social Structural Importance of Livestock

The importance of livestock among Toucouleur of the Boundou is evident from the role cattle play in centralizing the authority of the head of household. Cattle are a mark of status and prestige, and most importantly, they are an integral part of rites of passage. The head of household has authority over the family herd, which generally includes animals over which various family members have rights. A typical herd consists of animals that belong to the head of household, his wives, and his sons. There may also be animals belonging to his brothers, their wives, and children. Other relatives or friends can also consign animals to his care.

The head of household's authority over the herd is ultimate, although he has obligations to consult with individuals having rights over animals in the herd. Once consulted, the decision made by the head of household is final. The head of household also has ultimate sales authority, and is the sole representative of the household in negotiations over cattle sales (the situation is different for small ruminants). If a member of the household wishes to sell an animal, he/she consults with the head of household, establishes the price, and leaves the negotiations to the head of household.

The sacrifice and exchange of animals are extremely important in the Boundou. This reflects the importance of the event and is an indicator of the status and wealth of the

individual offering the animal. Cattle also play a major role in marriage. The bridegroom is expected to negotiate with the bride's family for the price to be paid in cattle. If the bridegroom has no cattle of his own, his father must offer cattle from his herd. The bride's father sends some animals with his daughter to her husband's compound as her dowry. As the daughter prepares to leave her father's compound an animal can be sacrificed to mark the event. An animal is almost always sacrificed to celebrate her arrival in her husband's compound.

A son may be given cattle at his baptism or at some later date. The animal may come from his father or grandfather, or be offered by his mother. A head of household explained the gift of cattle to a son in the following way: "when the time comes for him to marry he will have his own cattle and will not have to turn to his father for the bride price." Cattle may be sacrificed by sons to feed the mourners at their father's death. At the death of one village chief, two of his sons each sacrificed an oxen. Other members supplemented this by sacrificing goats and sheep.

Cattle are also sacrificed to mark events such as the ground-breaking for a new house, or may be offered to a griot who has come to praise and affirm the family's noble and historic genealogy. In one such incident the griot was seen to demand and receive a four-year old ox.

Much prestige can be derived both by the giver and the receiver when an animal is killed or donated. The animal given is in direct relationship to the status of the receiver, the importance of the event, and the means of the giver. A genealogical griot claimed that "his families" should give him an animal and request his presence at each rite of passage -- baptism, circumcision, marriage, first child, and death. This is not the common practice, but it underlines the importance of the sacrifice and exchange of animals in rites of passage and major events.

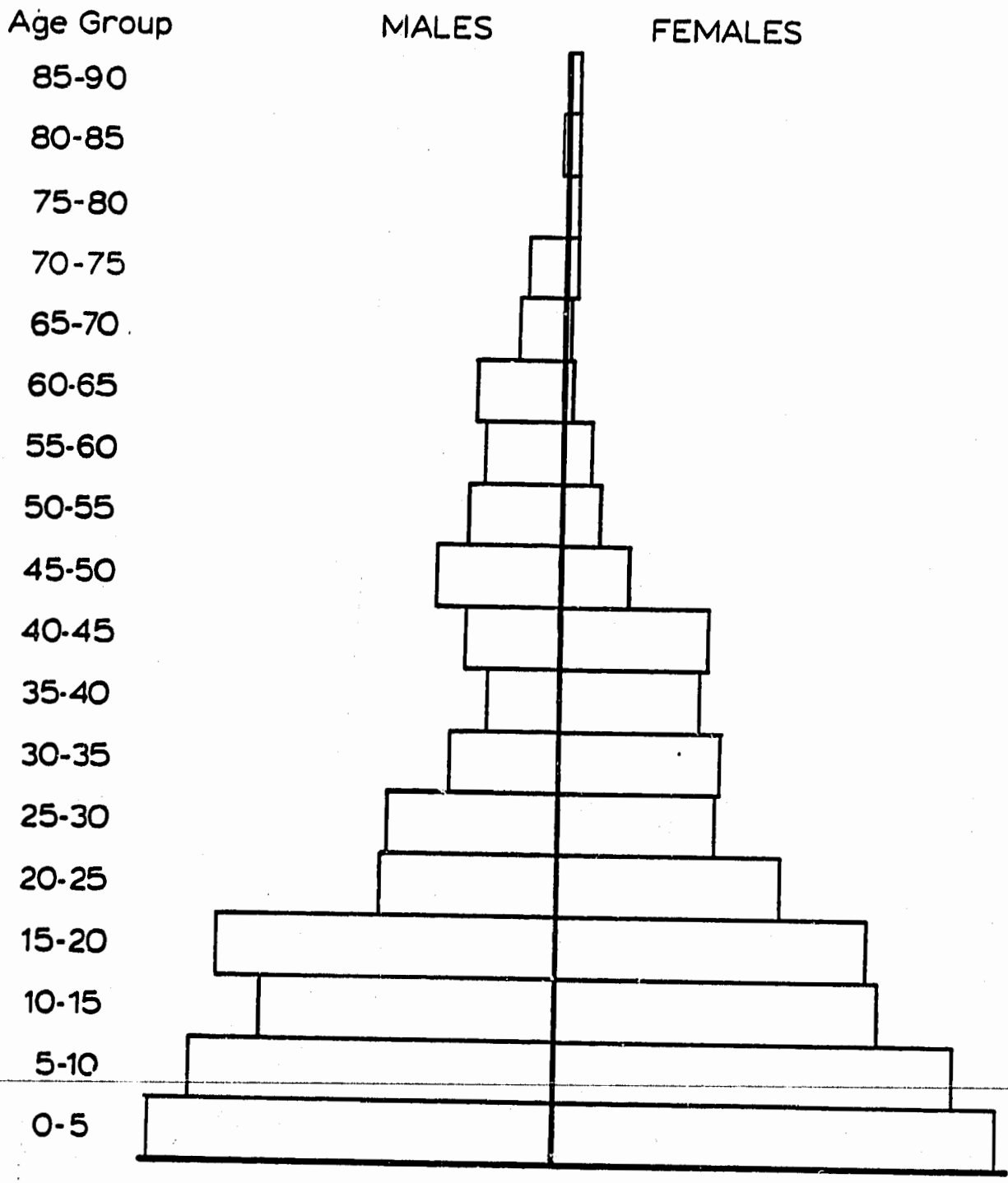
At the death of a herd owner all his personal animals are pooled. They are then divided into nine equal parts. One part is in turn divided among the wives of the deceased. The remaining eight parts are divided among the children. Daughters receive half of the sons' shares. When a woman has died, the procedure is similar except that her herd is divided into seven equal parts. The seventh is given to the husband, and the six remaining parts are divided among the children, daughters receiving half as much as sons.

1.5.4. Basic Demographic and Economic Indicators

Table 1.2. and Figure 1.1. show the age and sex distribution of the surveyed population, numbering 1,239. The most notable feature is the gap created by long-distance migration in the 30-35 and 35-40 age group for males; this has important

Figure 1.1.

Age/Sex Distribution of the Surveyed Population; All Zones



implications in the extent of family labor available both for farming and livestock herding in the area. Tables 1.3., 1.4., 1.5. and 1.6. summarize key statistics for each of the three zones. The average household size does not vary significantly from just under 8 members across zones. The number of household members currently away for wage employment does vary across zones, with means of 0.65 migrants per household in the Mbaniou Zone, 0.81 in the Sinthiou Fissa Zone, and of 1.12 in the Ololdou Zone. The number of former migrants in each zone suggests that out-migration is a more recent and extensive phenomenon in the Ololdou Zone, possibly because of more limited local opportunities.

TABLE 1.2.

AGE/SEX DISTRIBUTION OF THE SURVEYED POPULATION; ALL ZONES

Age-Group	Males	Females
85 - 90	0	3
80 - 85	1	3
75 - 80	0	3
70 - 75	9	3
65 - 70	11	1
60 - 65	21	2
55 - 60	19	7
50 - 55	23	9
45 - 50	30	17
40 - 45	23	36
35 - 40	18	34
30 - 35	26	39
25 - 30	41	38
20 - 25	43	54
15 - 20	82	75
10 - 15	71	78
5 - 10	88	97
0 - 5	98	108

TABLE 1.3.

HOUSEHOLD SUMMARY STATISTICS, ALL ZONES

Variable	Mean	Stand. Dev.	95% Conf. Interval
Number of Household Members	7.98	3.5	7.4 - 8.5
Number of Current Migrants	.81	1.05	.65 - .96
Number of Former Migrants	.31	.54	.23 - .39
Area Cultivated (ha)	1.24	1.16	1.06 - 1.41
Harvest Index	100	-	-
Agricultural Sales Index	100	-	-
Food Purchases Index	100	-	-
Household Cattle	49.5	41.1	42.7 - 56.2
Household Small Ruminants	27.4	21	-

TABLE 1.4

HOUSEHOLD SUMMARY STATISTICS, MBANIOU ZONE

Variable	Mean	Stand. Dev.	95% Conf. Interval
Number of Household Members	7.85	3.6	6.9 - 8.7
Number of Current Migrants	.65	.8	.46 - .83
Number of Former Migrants	.35	.55	.22 - .48
Area Cultivated (ha)	1.45	1.4	1.1 - 1.8
Harvest Index	150	-	-
Agricultural Sales Index	117	-	-
Food Purchases Index	114	-	-
Household Cattle	58	.51	43.8 - 72.1
Household Small Ruminants	23.2	18.2	-

TABLE 1.5.

HOUSEHOLD SUMMARY STATISTICS, SINTHIOU FISSA ZONE

Variable	Mean	Stand. Dev.	95% Conf. Interval
Number of Household Members	8.2	3.7	6.9 - 9.4
Number of Current Migrants	.81	1.2	.44 - 1.2
Number of Former Migrants	.41	.6	.21 - .61
Area Cultivated (ha)	1.18	.84	.95 - 1.4
Harvest Index	a	-	-
Agricultural Sales Index	65	-	-
Food Purchases Index	73.5	-	-
Household Cattle	47.2	36.5	36.3 - 58.2
Household Small Ruminants	16.1	10.7	-

TABLE 1.6.

HOUSEHOLD SUMMARY STATISTICS, OLOLDOU

Variable	Mean	Stand. Dev.	95% Conf. Interval
Number of Household Members	8.1	3.2	7.1 - 9.1
Number of Current Migrants	1.12	1.2	.77 - 1.5
Number of Former Migrants	.15	.3	.04 - .25
Area Cultivated (ha)	.95	.81	.7 - 1.2
Harvest Index	82	-	-
Agricultural Sales Index	107.6	-	-
Food Purchases Index	99.4	-	-
Household Cattle	42.1	31.2	32.9 - 51.3
Household Small Ruminants	51.6	38.4	-

The primary and secondary activities of the working age population in surveyed households are presented in Tables 1.7. and 1.8.

TABLE 1.7.

PRIMARY ACTIVITY OF THE WORKING AGE POPULATION, BY SEX

Primary Activity	Males	Females
Farmer	256	3
Herder	57	1
Homemaker	0	331
Shopkeeper	0	--
Small trade	2	8
Tailor	0	--
Artisan and local trades	9	3
Merchant	2	1
Government employee	--	--
Wage worker	10	--
Hunter	--	--
Herder	11	--

TABLE 1.8.

SECONDARY ACTIVITY OF THE WORKING AGE POPULATION, BY SEX

Secondary Activity	Males	Females
Farmer	66	43
Herder	168	1
Homemaker	0	5
Shopkeeper	7	2
Small trade	3	9
Tailor	0	--
Artisan and local trades	12	6
Merchant	0	0
Government employee	2	0
Wage worker	5	0
Hunter	4	0
Herder	2	0

Males clearly consider farming as their primary activity, herding being the most common secondary activity cited. Women consider homemaking and farming as their primary and secondary activities, the next most important activity being small trade. The relatively limited extent of occupations other than farming and herding (especially trades and crafts) is due to the particularly underdeveloped and isolated character of the project area. As we will see further in this report, this situation is changing rapidly, money sent back by migrants often is being used to set up village shops, for instance. Another area where significant change is taking place is that of education. Table 1.9. below shows the extent of attendance to different types of education systems by members of surveyed households. Aside from the overall low levels of attendance and the pronounced difference in school attendance between the sexes, the most striking fact is that the functional literacy could not have been tabulated three years ago. There is still a sharp difference in functional literacy access between men and women, but the results observed from the beginning of the program are encouraging. They also constitute a major agent of social change, as we shall discuss later in Chapter 3 of this report.

TABLE 1.9.

TYPE OF EDUCATION, BY SEX; ALL ZONES

	Males	Females
Koranic School	104	70
Public School	15	4
Functional Literacy	108	57

2. RESOURCE AVAILABILITY AND USE

2.1. AGRICULTURE

2.1.1. Rainfall, Land and Other Resources

There are two limiting factors in agriculture: extreme uncertainty about rainfall, and availability of labor. The area put under cultivation by the head of household is limited by the labor at his command. Agricultural labor and migration are at two ends of a scale. Loss of manpower through migration of able-bodied men must be potentially offset by spending migrants' remittances to buy grain. Several heads of household answered in this way when asked whether migration did not force them to sacrifice needed agricultural manpower: "if a man has four sons, he keeps two at home to work in the fields and sends two to France." The benefits of a potential cash inflow apparently make up for the loss of manpower in agriculture.

The economic system of the project area is firmly based on the symbiotic relationship between agriculture and livestock. The Toucouleur of the Boundou were agropastoralist before moving into the area and have continued their traditional pattern of livelihood. Village histories collected during the research reflect this fact. Both the more recent migrants from the Fouta and the older families dating back to the Sy family domination of the Boundou have continued the agropastoralist lifestyle of their forefathers. Historians have attributed Malick Sy's settlement in the Boundou partly to the search for arable land that had become scarce in the Fouta Toro (Ronçon, 1984:42). Many villages in the project zone were established during the first half of the 20th century. There appears to have been two trends: a move away from the early settled villages along the Falémé where there was pressure on available land and probably conflict among brothers, and a migration from the Fouta into the Boundou by Toucouleur looking for land.

In many cases the original settlements were temporary, settled only during the agricultural season. These villages became permanently inhabited later as sources of water were developed and the soil proved to be good for agriculture. In all interviews concerning the choice of sites for present villages we were told that the presence of good pasture in the area played an important role in the decision to settle.

The important role played by agriculture is exemplified in the Sinthiou Fissa Zone by a group of purely agricultural villages just east of the escarpment. These are inhabited only during the growing season as long as standing water is available. Because of the geological features of this area it is impossible to obtain groundwater. As soon as there is

no more standing water, the villages of Birfal, Gourel Maman Ndieye, and Waly Diala become deserted. One must note, however, that these villages do not appear to be temporary. They each have their share of large tin-roofed structures. Passing through these villages during the dry season one is likely to see one of its inhabitants replenishing his grain stock from his granary.

These three villages are politically and socially integrated into the village of Ourousoulé, located in the center of the zone. Ourousoulé does not have adequate arable land but has a steady flow of well water which permits the watering of most of their cattle during the dry season. The mother village, Ourousoulé, is seven to ten kilometers away from the seasonal villages, but serves as the chief political unit. Each of the satellite villages designates their village chief as the chief of Ourousoulé, who is himself a seasonal migrant from Waly Diala.

The settlement history of one village emphasizes the economic interdependence of agriculture and livestock in the Sinthiou Fissa Zone. According to the history of migration and the settlement of this village, the three brothers who arrived at the present site only owned a goat. They sacrificed it at the site where they decided to settle, but the abundance of their crops enabled the brothers to sell grain and buy cattle. Their success in agriculture thus contributed to the development of their herd. The villagers stated that the second surge in the number of cattle was due to remittances and to investments by migrants.

The extremely uncertain patterns of rainfall strongly influence the social and economic lives of the population in the project zones. Last year between the two villages of Mbaniou and Ndia, only seven kilometers apart on a north-south axis, there were on several occasions differences of 20 to 50 mm in rainfall. Not only is the variation in precipitation an important factor, the irregularity of the rains can be extremely disruptive as well. During the 1983 agricultural season, the maize crop was almost entirely lost throughout the project area because rains essential for the autopollination of the crop did not occur at the right time.

In all project zones people see themselves as sedentarized agropastoralists, but the actual extent of farming is limited, especially in view of labor constraints. For example, the average area cultivated by households in the Mbaniou, Sinthiou Fissa and Ololdou zones was in 1984 of 1.45, 1.18 and 0.95 hectares, respectively. These figures are quite low, even by comparison with other traditional farming societies of Senegal. The overall low level of cultivation reflects the fact that existing conditions make returns to agriculture precarious, and provide a lower return on investment than the chief alternatives, livestock raising and long-distance migration. Differences between zones

reflect disparities in resource endowment and population pressure; Sinthiou Fissa and Ololdou, in general, have a lower agricultural potential than the Mbaniou zone, and tend to rely slightly more on migration than their neighbours of the Mbaniou zone. Further in this report, as we examine the value of livestock sales and cash flows from remittances, the rationale for this pattern of resource allocation will become quite evident.

One should note that the figure given as the mean area cultivated per household does not hide much of a skewing effect in either direction. Table 2.1., and Figures 2.1. and 2.2. show that the distribution of land worked by individual families in the three zones is rather even.

TABLE 2.1.

DISTRIBUTIONAL ANALYSIS OF AREA CULTIVATED PER HOUSEHOLD
(ha)

	Prob.	Quantile	Confidence Interval
1. Mbaniou			
	.25	.59	.26 - .69
	.5	1.04	.73 - 1.2
	.75	1.8	.26 - 3
2. Sinthiou Fissa			
	.25	.43	.28 - .76
	.5	.88	.76 - 1.5
	.75	1.74	1.5 - 2.02
3. Ololdou			
	.25	.43	.106 - .48
	.5	38	.46 - 1.2
	.75	59	1.17 - 1.67

The order of importance for crops cultivated across zones remains constant; sorghum receives most of the acreage, 46 percent and 55 percent respectively in the Mbaniou Zone and Sinthiou Fissa Zone, and up to 80 percent in the Ololdou Zone, where very little millet is grown. Millet comes second in the Mbaniou and Sinthiou Fissa zones (32 percent and 15 percent of acreage), followed by maize. Very little land is devoted to peanuts, except in the Sinthiou Fissa Zone. Finally, small patches of rice are found in certain areas of the Ololdou Zone.

Data collected in a village in the Mbaniou Zone show that 20 households in the sample cultivated a total of 17.7 hectares. Forty-six percent of the area under cultivation was in

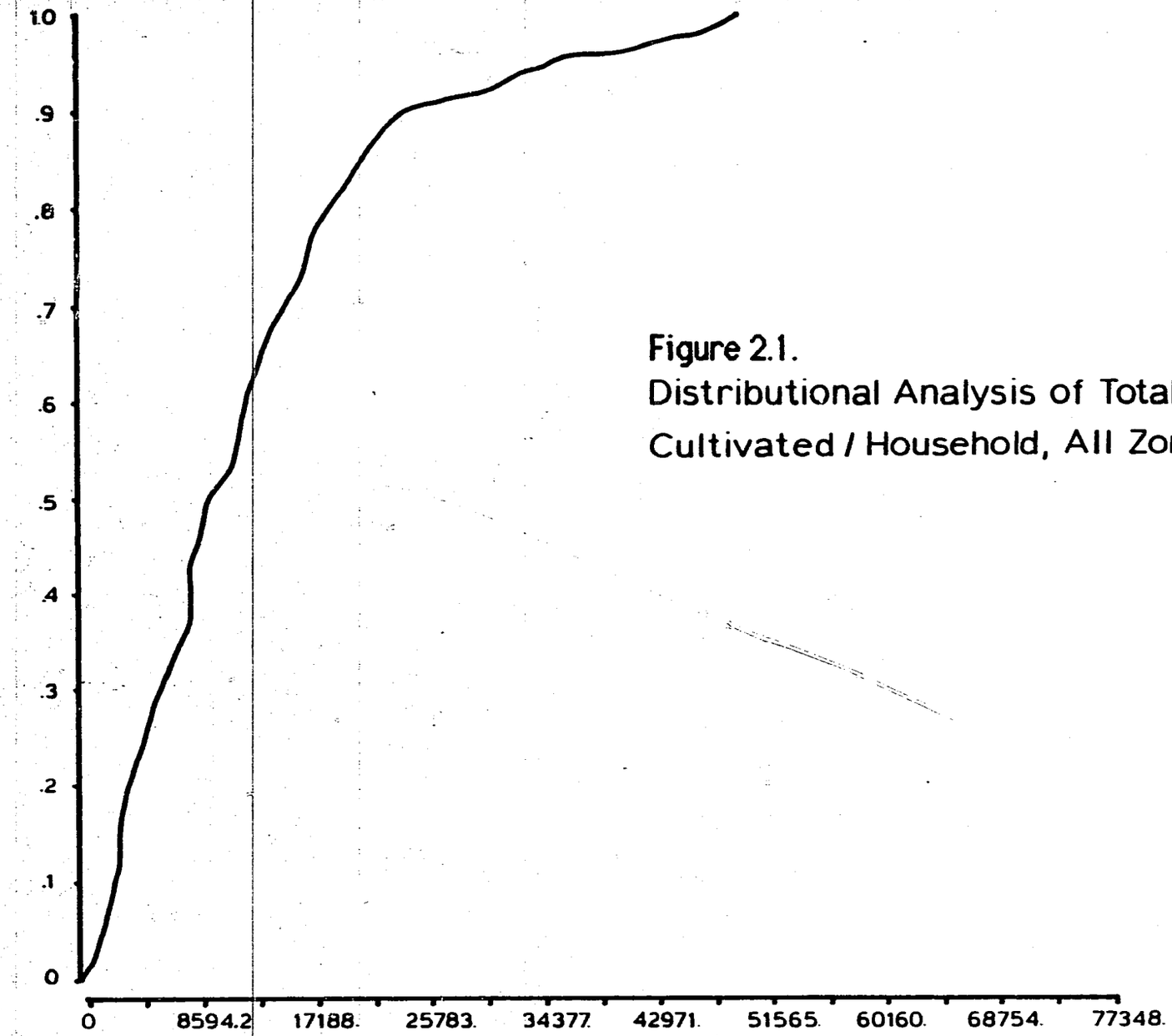


Figure 2.1.
Distributional Analysis of Total Area Cultivated / Household, All Zones

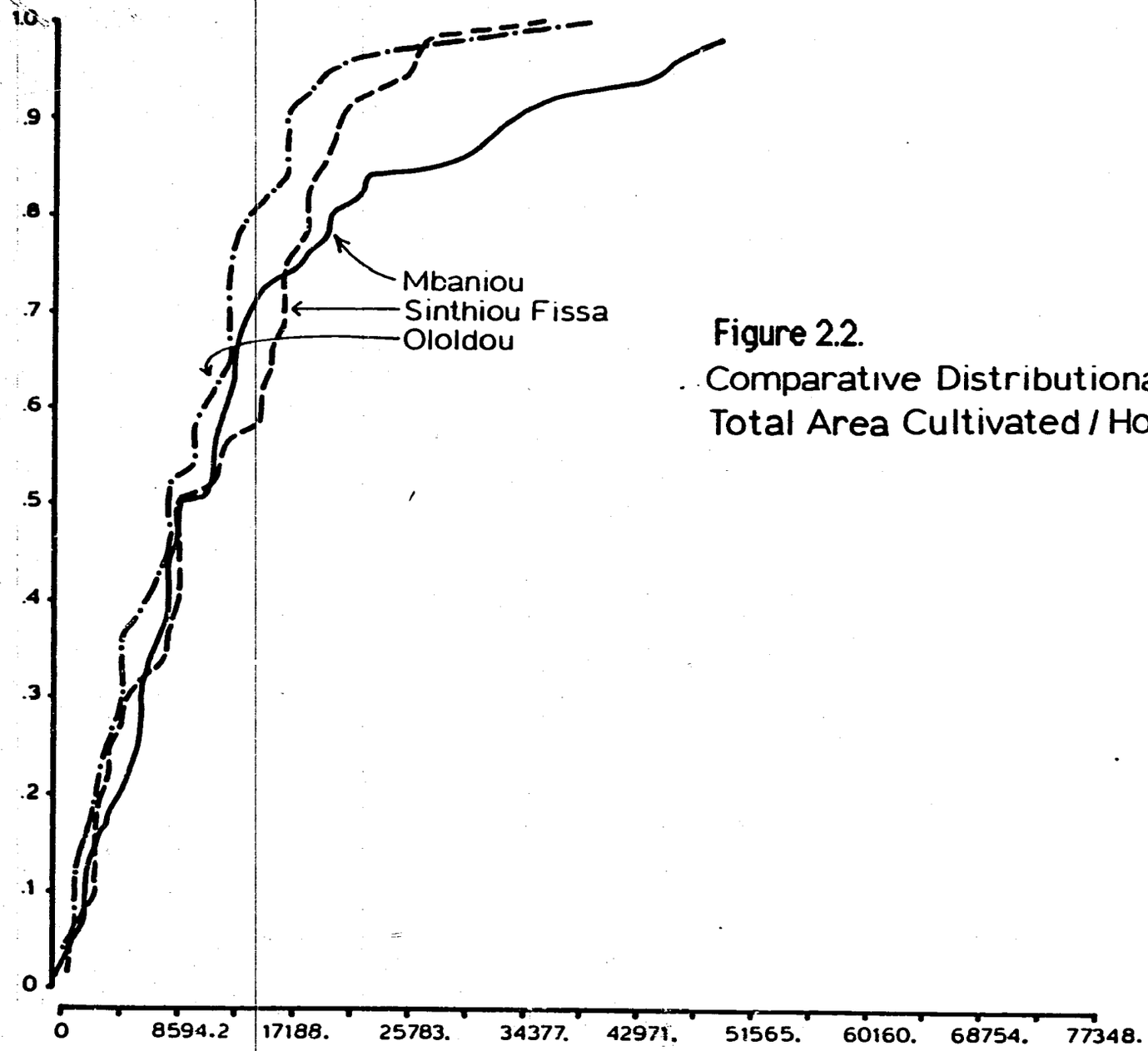


Figure 2.2.

Comparative Distributional Analysis of Total Area Cultivated / Household, By Zone

sorghum, 37% in millet, 11% in maize, and 6% was in peanuts, considered primarily a woman's crop (see Table 2.2.). Small grain millet is in many cases preferred for meal preparation; however, millet is difficult to grow because of its susceptibility to insects, rogouva worm infestation, attacks by blister beetles, charcoal smut and bird devastation. Evidence of all of these was seen in the fields.

TABLE 2.2.

CROPS AND AREA UNDER CULTIVATION, MBANIOU ZONE

Crops	Area Under Cultivation	Percentage
Sorghum	8.1 Hectares	46%
Millet	6.5 Hectares	37%
Maize	2 Hectares	11%
Peanut	1.1 Hectares	6%
Total	17.7 Hectares	100%

As one might expect, agricultural labor allocation closely reflects the emphasis given to the various crops. Table 2.3. below shows the proportions of family labor allocated to the various crops. The same table shows the extent to which hired labor is used on various fields; millet, sorghum and maize receive about equal -- and relatively low -- shares of hired labor as a proportion of total labor.

TABLE 2.3.

AGRICULTURAL LABOR ALLOCATION; OVERALL SAMPLE

	% of Total Labor	% of Labor Hired
Sorghum	38.6	7.25
~~Maize~~	~~28.4~~	~~6.06~~
Millet	22.4	8
Peanuts	5.6	1.9
Millet/Sorghum	5.3	.73
Total	100%	

In the project area farming does not follow complex rotation patterns, and the majority of fields are single cropped, although some interesting potential for cereal/cowpea association has been noted by the Range Management Researcher. The most common patterns of crop rotation are summarized in Table 2.4. below, which compares the crops standing on measured fields in 1984 with crops cultivated on the same field one and two years previously.

TABLE 2.4.

CROP ROTATION PATTERNS, ALL ZONES

Current Crop	Crop 1 year ago	Crop 2 years ago	Crop 3 years ago
Sorghum	Sorghum, millet	Sorghum, millet, maize	Sorghum, millet, maize
Maize	Maize	Maize, sorghum	Maize, sorghum, millet
Millet	Millet, sorghum	Millet, sorghum, maize	Millet, sorghum, maize
Peanuts	Peanuts, sorghum, millet	Peanuts, millet, maize,sorghum	Peanuts, maize, sorghum, millet
Rice	Rice	Rice	Rice

As part of our data collection on agriculture we asked heads of households to estimate their yield for the present (1983) agricultural season and the previous one. Yield figures obtained from villagers in the Mbaniou area reveal that the 1983 yields were between 45% to 75% less than those of 1982. They attributed the difference to the lack of rains. One should remember that insects, birds and other blights also play a role. For the four crops grown locally the yield reduction from the 1982 to the 1983 season ranged from 36% for maize, possibly an underestimation, to 75% for peanuts. Table 2.5. below shows difference in production of several crops from one year to the next in a village of the Mbaniou zone.

For the project area as a whole, yield figures ranged from 600 to 800 Kilograms (Kg) of sorghum per hectare, while for maize yields ranged from 530 to 1,280 Kg per hectare. Millet yields, however, were only about 600 Kg per hectare. We found that obtaining yield data was a sensitive and difficult matter. In a few instances it would have been possible to weigh the total crop as it was being placed in the granary, but our request was denied.

TABLE 2.5.

SELF-REPORTED YIELD, MBANIOU ZONE
1982/83

	Yield Total Crop 1982-Kilo	Yield Total Crop 1983-Kilo	Difference Percentage Crop In Yield - 1982/1983
Sorghum	809	447	45%
Millet	984	597	40%
Maize	516	334	36%
Peanuts[a]	855	220	75%

NOTE: [a]Peanuts are generally a woman's crop. These are only partial figures on 7 households.

2.2. AGRICULTURAL CALENDAR AND PRACTICES

2.2.1. Pulaar Seasons and Farming Terminology

People recognize five seasons, which are based on changes in local weather conditions; they are as follows:

Ndungu	the rainy season, from July to the end of October
Kawle	a short one-month season around harvest time
Dabunde	from December through the end of February
Ceedu	from mid-February to the end of May
Demminare	a transitional season, during June

The terminology used for farming and animal husbandry is quite rich among the Toucouleur; below is a sample of terms referring to specific farming activities:

Naure	select the location of a field
Lewre	clear trees, bush and stumps
Dupitere	burn cut branches and brush
Soppitere	cut branches and brush (2nd year)
Aawre	seeding on humid ground
Munnere (or Hulde)	seeding on dry ground
Remde arano	1st weeding
Mbeytagol	2nd weeding
Tabbagol	3rd weeding

Tutade	transplanting
Doftade	thinning plants
Deenal fof	watch over crops
Hiude	chase birds away
Nyaamtaade	1st small harvest
Naro	bend stalks to the ground
Konyal	harvest
Vinde	putting animals to graze on stubble
Sooynde gesa	fallow
Doftal	collective work
Ndemu	agricultural work done for a father-in-law.

2.2.2. Agricultural Calendar

February to June: This time involves the clearing and preparation of new fields. Small trees and brush are cut down and stumps are burned to the ground. A small hand axe is the main tool. Because of the physically demanding nature of this work it is primarily done by the head of household and young men.

April to June: The method of field preparation is not entirely consistent throughout the three zones. There is more variation between villages than within one. In some villages a major effort is made to clean the fields of all remaining debris from the last harvest and weeds. Organic material is raked, piled and burned. The gathering of dried manure along with it is not deliberate, but some of the manure is also piled up and burned. In some villages burning and cleaning is not done, to let the organic matter mulch the soil and give it greater moisture retention. A rake (one of Western design is a prized tool for this work) and a short-handled hoe are used. This task is done by men or young boys.

June: Depending on rainfall the fields are seeded and plowed. There may be some light and scattered showers in April or earlier, but seeding takes place after what is considered the first serious June rain. Fields are seeded starting with millet, corn, sorghum, and finally peanuts. A plow pulled by a horse or donkey is common, but combinations of horses and donkeys are also seen. A stick is used to make the hole where the seed is dropped in by hand. When the field has not been plowed, a large L-shaped metal-tipped hoe is used to break the ground before planting. The work team consists of almost any combination of household members. When a plow is used, a boy leads the team, followed by men, women, boys or girls planting the seeds. If the second rain does not occur in time, fields are reseeded.

June and July: The fields that have been planted are fenced in, and watch towers and shelters are built. These are to be used by the family to guard against birds and wild animals as the crop matures. The fences around the fields close to villages generally have to be rebuilt every year. Material from old fences is used for construction projects around the compound. For fields further from villages, thorn bush fences have to be either replaced or reinforced. The tools used are the short-handled axe and a metal-tipped digging stick. Small trees and thorny bushes are cut down and dragged or carried to the fields. The most elaborate fences are made up of a series of split logs dug into the ground a few inches apart. Fencing and the construction of watch towers is done by men young and old; boys help drag thorny branches to the fields.

June to August: At that time most people are cultivating planted fields. Timing depends on the pattern of rains. Fields may be cultivated two or three times depending on weed growth and rains. Weeding is done with a short-handled hoe by the head of household and his sons. It is by far the most demanding task of the labor calendar, and is usually done twice during the agricultural season. While doing field measurements, we asked the head of a household why we were including what looked like a weed-covered fallow section of his field. He replied that the area had been planted but that he had been unable to cultivate it. Upon close inspection the sorghum stalks could be seen among the weeds.

July to August: The fight against insects in millet fields begins. If insecticides are available, men dust the fields. If no insecticides are available, young boys go into the fields at the height of the blister beetle season, carefully catch a large beetle, dismember it and leave it to rot in the field. The conventional wisdom is that the smell of the rotting beetle will discourage other blister beetles from entering the field. Smoldering fires are also set in hopes that the smoke will chase insects away. Men may walk through their fields carrying smoldering and burning branches to spread as much smoke as possible.

August to harvest time: Fields are guarded against attacks from warthogs, green monkeys, baboons and birds that feed on the grain of the millet spike just before harvest. To guard against wild animals, young men often spend nights in the fields.

August to October: In the project area, approximately 100 km wide by 100 km long, there are marked differences in agricultural calendars. For instance, there is approximately a two-week interval between the sorghum harvest in the three zones. During the 1983 season the harvest took place first in the Mbaniou Zone and was followed by the Ololdou and Sinthiou Fissa Zones.

Corn fields are harvested first, followed by millet and sorghum fields. When corn is picked, husks are pulled back, and the ears are left to dry for a few days before storage in

the family granary. Millet is cut from the stalk, placed in small piles to dry in the field and stored. Sorghum is cut and moved to the household's granary. Every member of the family participates in some aspect of the harvest; younger men and heads of households cut the crop while women and children help hauling it to the granary. After harvest, sorghum stalks are cut and carefully stored out of reach of livestock. They will serve as fencing and shading material in the coming year.

October or the end of harvest time: As soon as the fields have been harvested, fences are taken down and animals are allowed to feed on crop residue. During this period large ruminants are not tied down, and are allowed to wander throughout the village and fields at night.

December to June: When cattle have returned from bush camp, they are tied down on a rotating basis over the fields so that manure may be spread as much as possible. The fields that receive the most manure are the ones closest to the village and that will be planted in corn. This task is done by men and boys under the supervision of the head of household.

2.3. SOCIOCULTURAL FACTORS IN AGRICULTURE

2.3.1. Social Structure and Labor Allocation

Recurrent subsistence crises may well be a recent historical phenomenon, but the reliance on grain crops in the Sahel is not. The social organization of the household reflects the need of the head of household to mobilize and depend on manpower from its members. According to the traditional pattern of authority within the family still in force with the project area, the senior brother wields authority over all his juniors and their progeny.

Ideally, this would represent four generations of brothers, but most often two to three generations are under the leadership of the eldest brother. In some households, particularly those of village chiefs, there may be three generations under the leadership of the senior brother. This system theoretically permits the head of households to mobilize a maximum labor force for agriculture and other essential tasks.

2.3.2. Women in Agriculture

Traditionally women have been responsible for the cultivation of lowland rice, peanuts, and garden crops, primarily niébé and okra. There is very little lowland rice cultivation in the project area because of the lack of appropriate depressions and diminishing rainfall. However, where land and water permit the tradition is maintained.

In Ololdou there were seven rice fields representing a total of 3,206 square meters under cultivation. Most of the fields were quite small: three fields were approximately 100 square meters, three others were around 300 square meters, and one field was 1700 square meters in size. Yield figures for these fields do not seem very reliable although there is a constant relationship between the 1982 and the 1983 seasons. The 1983 yield appears to have been one-third less than for 1982.

Peanuts are not grown as a cash crop but mostly for family consumption. The area devoted to peanuts depends primarily on the availability of appropriate soils. A greater area is devoted to peanuts in the Sinthiou Fissa Zone, particularly in the western part just east of the escarpment, where the soils are suitable.

2.4. ECONOMIC INTERDEPENDENCE OF AGRICULTURE AND LIVESTOCK

The essential feature of agropastoralism base in the project area is that agriculture and livestock play important complementary roles both in the subsistance and cash economies. In terms of agriculture, herds are rotated over the fields to benefit from their manure. As soon as the crops have been harvested and sorghum stalks needed for fencing and shading set aside, the herds are allowed to feed on the stalks that remains, initiating the manuring process for the next year.

Periods of high labor demand for livestock occur primarily at times of low demand for agriculture labor. This is true with the exception of the last weeks of the dry season when field preparation and the drawing of water for the herds must be done simultaneously.

Livestock accumulation plays an important double role. Livestock on the hoof is first a saving that can be sold in times of need. Accumulation of livestock is also a form of risk aversion and investment. A large number of cattle can minimize the losses that may occur from disease, drought or attacks on the herd by predators.

The important role played by agriculture as a means of cattle accumulation may well be changing due to the worsening climatic conditions, and the difficulty in accumulating enough of a grain surplus. Migration may now have taken over the role played by grain accumulation in the past. Labor migration brings in cash that can be used to fill the subsistence gap in a bad year, or to be used to invest in cattle.

2.5. LIVESTOCK

2.5.1. Typology and Extent of Herds and Flocks

Cattle in the project area represent a cross between Bos indicus and Bos taurus-type animals; they are shorter than the pure Sahelian Zebu, but taller than N'Dama-type cattle found further south. The local breed is known as Diacori. People in the area are sensitive to small differences between breeds and distinguish between the local Diacori and Oreeji, smaller cattle from southern areas (more like N'Damas); Pulli, taller Diacori from the north-east; and Nianinke, tall Diacori from the north-west or Ferlo area.

Small ruminants are of the lower Sahelian Djallonke-type, some tall Djallonke-like goats called Ndogoota.

Table 2.6. below shows the average size of cattle and small ruminants holding per household, for each project zone in 1984.

TABLE 2.6.

LIVESTOCK OWNERSHIP BY ZONE, 1984
(Average No. of Head/Household)

	Cattle	Sheep/Goats
Mbaniou	58	23.2
Sinthiou Fissa	47.2	16.1
Ololdou	42.1	51.6

The emphasis on small ruminants in the Ololdou zone is most likely due to less abundant and lower quality forage resources than in the other zones. Tables 2.7. and 2.8., and Figures 2.3. and 2.4. show the distributional analysis of cattle and small ruminant ownership across households for the three zones. There is naturally some unevenness in livestock ownership between families, especially in the Mbaniou zone, but not to an extreme degree. The most striking example of unevenness in cattle distribution does not in fact appear in these numbers. Cattle ownership in the village of Diare M'Bolo, in the Mbaniou zone is much above that of other communities (because of the community's social status and good marketing connections). However, this cannot be precisely documented because the total size of Diare M'Bolo herds could only be estimated, rather than surveyed, as was the case for the other villages.

TABLE 2.7.

CATTLE HOLDINGS, BY ZONE/VILLAGE

Mbaniou		Sinthiou Fissa		Ololdou	
Toulekedi	154	Woubowol	111	Ololdou	93
Sowol	101	Ourousoulé	55	Gourel Dialoubé	132
Diare Maboubé	96	Arigabo	101	Sira Amadi Bocar	134
Mbaniou	73	Sinthiou Fissa	71		
Total	424	Total	338	Total	359

TABLE 2.8.

DISTRIBUTION OF SMALL RUMINANTS; BY ZONE

	Goats	Sheep	Total
Mbaniou	269	171	440
Sinthiou Fissa	149	46	195
Ololdou	214	104	318

The livestock census carried out for surveyed households, nevertheless, allows us to answer a critical question: "has the size of herds in the project area increased significantly over the last few years?" Table 2.9. suggests that it did not, at least in the Mbaniou zone, which received most of the livestock-oriented project interventions.

TABLE 2.9.

COMPARISON OF HERD/FLOCK SIZE PER HOUSEHOLD, 1976-1984

	1976	1984
Cattle	66	58
Small ruminants	23.6	23.2

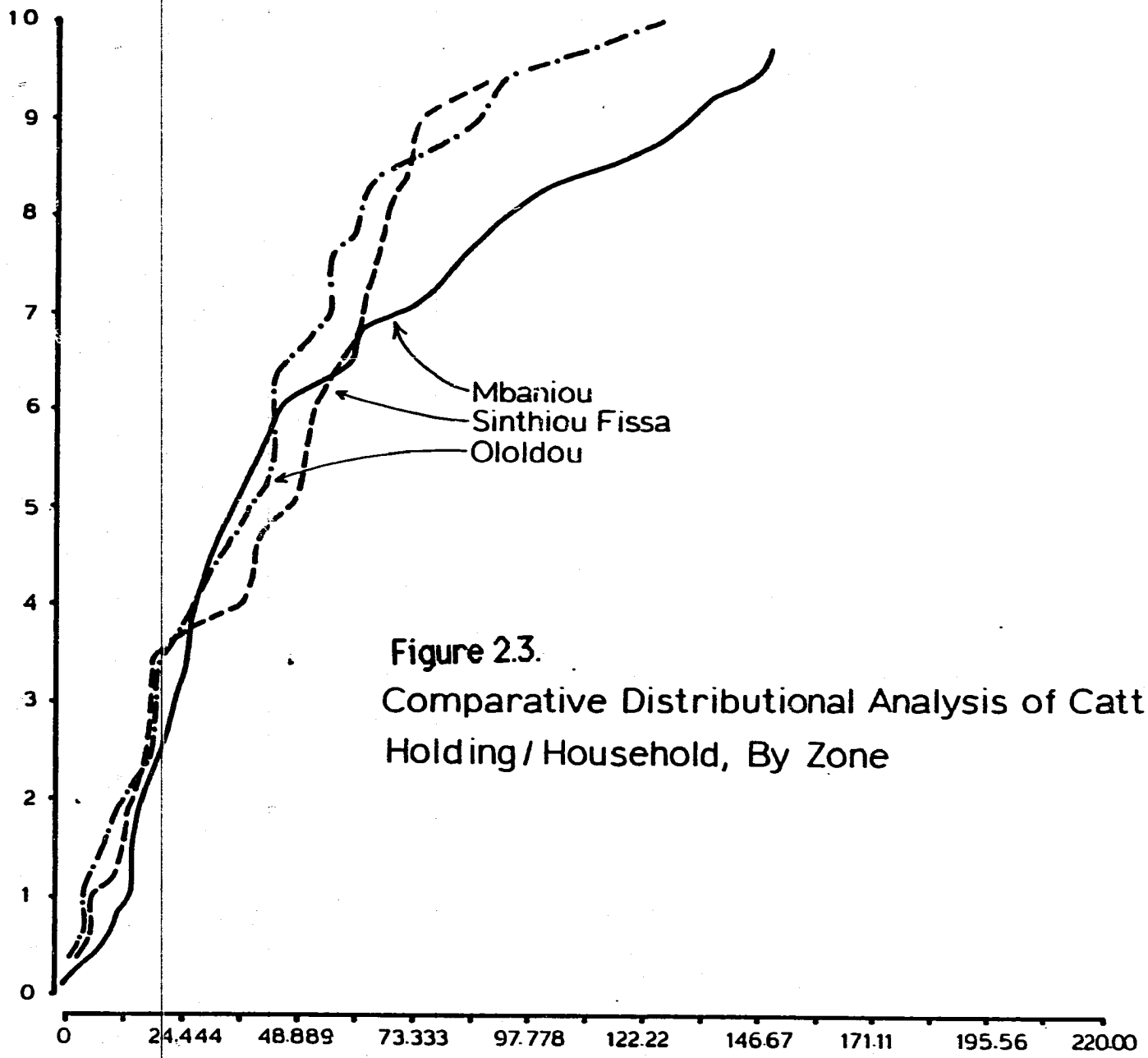


Figure 2.3.
Comparative Distributional Analysis of Cattle Holding / Household, By Zone

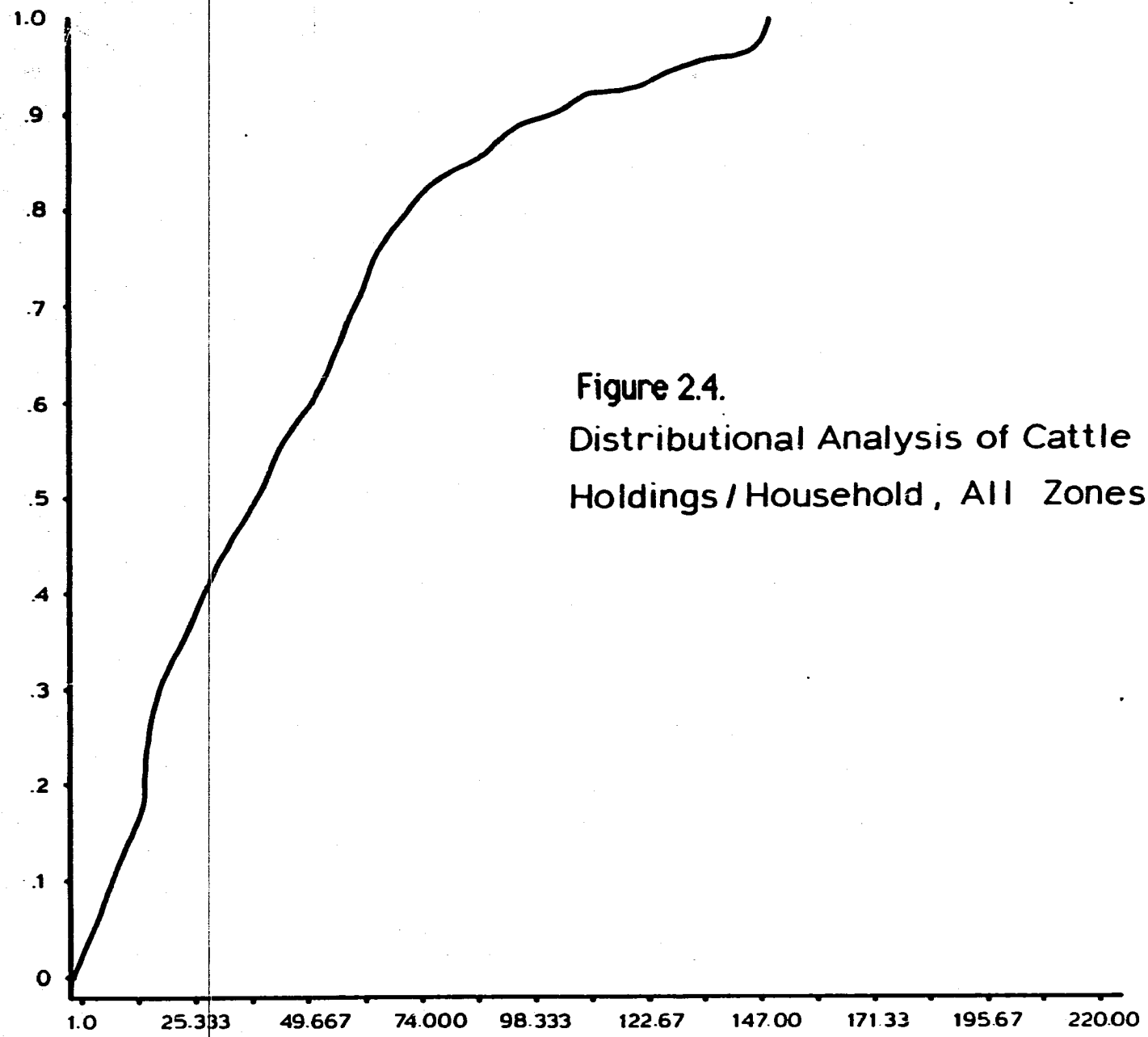


Figure 2.4.
Distributional Analysis of Cattle Holdings / Household, All Zones

The overall size of herds and flocks has not significantly changed during the interval. One might suggest that although herd size has not changed, gains in fertility, survival and marketing of animals have taken place, and that increased benefits are being derived from the same equilibrium number of animals. Precise baseline data for small ruminants are not available, but in the case of cattle, a comparison of herd structure about eight years ago and today shows that age/sex distribution in standing cattle herds are closely matched (see next section). Together with information on yearly movements of animals in and out of family herds throughout the year, this allows us to present further on some conclusions on the impact of project activities on livestock.

2.6. LIVESTOCK OWNERSHIP AND MANAGEMENT

2.6.1. Management

Perhaps to a greater extent yet than for agriculture, the Toucouleur have a rich lexicon of terms referring to livestock and animal husbandry. The following list offers a glimpse of the variety and specificity of such terminology:

Mbalndi	herd in general
Sefre	half herd
Sawru	herd of 100 head
Kabi didi	herd of 200 head
Ornude	take the herd out to pasture
Diofnude	bring a herd back to the village
N'gaynako	herder
Gorwori	cattle belonging to the head of household (exclusive right to the head of household)
Tene	cattle received by a woman when she marries, belongs to her and to her children
Donaani	inherited cattle, belong only to the inheritor
Diili	lactating cows loaned by relatives or allies, the household has use of the milk
Kalfinaadi	animals kept on behalf of relatives or allies; household has right of use of any milk

Table 2.10. and Figure 2.5. show the age/sex distribution of cattle in the overall project area, Tables 2.11. through 2.13. present equivalent data by zone. The percentage

of females in the herd (66 percent overall) suggests relatively heavy destocking of surviving males; the proportion of cows in total herds (46.8 percent) is very similar to that found in traditional cattle herds of the Senegalese Ferlo. It is actually difficult to reconcile the high proportion of females in herds and low observed rates of offtake until one realizes the importance of combined mortality of young and replacement purchases of heifers.

TABLE 2.10.

AGE/SEX DISTRIBUTION OF CATTLE, ALL ZONES

Age	Bulls and Young Males	Steers	Females	
0-1	120			121
1-3	93	9		94
4-7	61	50	Pregnant	78
			Lactating	94
			Other	72
7-10	33	14	Pregnant	53
			Lactating	70
			Other	58
over 10	0	0	Pregnant	17
			Lactating	46
			Other	35

Data from the mid-1970s provided estimates of calf mortality in the 0-1 age group ranging anywhere from 5 to 40 percent per annum (the latter number being hardly consistent with historical sustenance of herds). Fertility and fecundity rates for cows were quoted as being from 52 to 57 percent, annually. More systematic research by project staff and our own teams suggest that calf mortality in the 0-1 age group is more on the order of 20 percent annually. The survey on life histories of cows, on the other hand, showed that the number of calvings per reformed cow ranges from 3 to 9, with a mean of 5 and a standard deviation of 1.3. This suggests a fecundity rate of over 60 percent per annum, and an average number of calvings equal or superior to what is found in traditional herds of the Senegalese Ferlo.

TABLE 2.11.

AGE/SEX DISTRIBUTION OF CATTLE, MBANIOU ZONE

Age	Bulls and Young Males	Steers	Females	
0-12 mos.	49			48
1-3	35	4		36
4-7	23	21	Pregnant	29
			Lactating	36
			Other	26
			Sterile	1
7-10	9	5	Pregnant	22
			Lactating	28
			Other	20
over 10	0	1	Pregnant	8
			Lactating	16
			Other	7

TABLE 2.12.

AGE/SEX DISTRIBUTION OF CATTLE, SINTHIOU FISSA ZONE

Age	Bulls and Young Males	Steers	Females	
0-12 mos.	39			41
1-3	29	1		26
4-7	17	15	Pregnant	30
			Lactating	29
			Other	20
7-10	12	8	Pregnant	15
			Lactating	14
			Other	17
over 10	0	1	Pregnant	6
			Lactating	8
			Other	10

TABLE 2.13.

AGE/SEX DISTRIBUTION OF CATTLE, OLOLDOU ZONE

Age	Bulls and Young Males	Steers	Females	
0-1	32			32
1-3	29	4		32
4-7	21	14	Pregnant	19
			Lactating	29
			Other	16
7-10	12	1	Pregnant	16
			Lactating	28
			Other	21
over 10	0	0	Pregnant	3
			Lactating	22
			Other	18

As we will see further (in the section on marketing), the offtake rate, expressed in animals sold as a percentage of the total herd is relatively low, estimated to be 6 to 8 percent (mostly males around age five). Table 2.14. summarizes the results of an 18-month survey of herd inventory entries for 120 households. Although people were invariably reluctant to give information on their herd as a whole, they were much more willing to tell interviewers about changes in the herds, as they happened.

The data show that the reasons for decreases in herd numbers of males could be attributed to sales (60 percent), and mortality (33 percent); for females, where sales are much lower in absolute numbers, sales accounted for 34 percent of decreases in numbers of females, and mortality, for 61.5 percent. Finally, for steers, which have reached ages where mortality is relatively low, sales accounted for 75 percent of decreases in numbers in the age group.

Both the survey of life histories for cows and the ongoing tracking of herd inventories indicated that purchases of cattle (essentially females) play an important role in maintaining herd sizes to the level people want to sustain. Table 2.14. shows that for males, purchases contributed 3.5 percent of additions to cattle herds, the rest being imputable to births within the herd. For females, on the other hand, over 10 percent of animals added to the herds were purchased, at ages ranging from three to four years.

The overall picture emerging from our data on herd composition and management practices suggests relatively high fertility and fecundity rates for cattle (the average number of miscarriages per reformed cow was 0.24). However, mortality in younger ages remains very high, which leads on the one hand to a low actual offtake rate, and on the other to a need to maintain overall herd productivity by purchases of females in early reproductive ages. The net effect is the maintenance of cattle holdings near the current levels over time, and the maximization of benefits from cattle -- given high mortality rates -- by purchases of reproductive stock. Everything leads us to believe that the further necessary decreases in mortality of young animals would translate into a reduction of outlays for the purchase of reproductive stock rather than sharp increases in herd numbers. Not only are heifer purchases a heavy drain on area households, the number of cattle that families can currently carry is constrained by water resources and availability of manpower for the most labor-intensive tasks (especially watering animals in the dry season). It is also important to note that the pattern of heifer purchases is probably of long standing. Reducing calf mortality must therefore be considered as an objective having sizeable immediate impact on family budgets as well as longer-term benefits. Herders are very much aware of this, in addition to bringing their animals in for free vaccination programs, they have spent relatively large sums buying cattle medicines sold at cost by the project.

TABLE 2.14.

ORIGIN OF ANIMALS COMING INTO HERDS DURING SURVEY
(in %)

	Males	Females
Birth	96.3	88.6
Purchases	3.5	10.2

	Males	Females	Steers
Mortality	33%	61.5	14.3
Sales	60%	34	75

Small ruminants make an important contribution to the local economy (15 percent of farm income), but actual and potential benefits are even further apart for them than in the case of cattle. Proportionally, for example, mortality is twice that of large ruminants. Animal health extension has traditionally concentrated on cattle, by and large, ignoring sheep and goats, and this project is no exception.

2.6.1.1. Livestock calendar and practices

A synthesis of livestock calendar and practices is given below; although patterns of animal husbandry vary somewhat between zones, the general rule is that people attempt to minimize labor allocation to herd management tasks. The most demanding labor requirements clearly have to do with the limited availability of water, which is why the notion of ponds (especially ponds close to villages) was well received by populations in the area.

December to June: Drawing water for large ruminants. This task varies greatly according to the location of the village and the availability of water.

In the Mbaniou Zone the task of drawing water starts as soon as the artificial ponds and natural sources of standing water have dried up. Depending on the location of the village and the retention capacity of the ponds the time period for starting this task ranges from December to mid-February.

Drawing water from wells is usually done by a man and a boy or young man relying on animal traction. A horse is most commonly used but some households use a donkey. The animal pulls a 20 liter inner tube bag out of wells that are 35 to 55 meters deep. The water is then poured into hollowed out logs or 200 liter oil drums cut in half. It takes a man and a young boy about two hours to water 100 head of cattle. Without animal traction it takes four men two hours to do the same task.

In the Sinthiou Fissa and Ololdou zones, since artificial ponds are not available in these areas and there are no major natural ponds, the drawing of water for large ruminants starts sooner; depending on the rains, in December or earlier. Because of geological factors in the Sinthiou Fissa and Ololdou zones, wells are not always available. In many villages ceanes are dug. A ceane is a shallow temporary well two to five meters deep dug in the sandy bottoms of seasonal streambeds. The work in ceanes is done by men and young men. Two men take turns dipping water out of the ceane with a small 4 or 5-liter calabash attached by a baobab bark rope to the end of a 3 to 4-meter pole. However, ceanes must be constantly maintained so that more than half of the time spent watering cattle is spent improving the ceane. In addition, ceanes may not recharge sufficiently every day, so that two may have to be used on alternate days. They also provide extremely aleatory sources of water.

It takes two men about one hour to water 100 head of cattle, another hour is spent deepening and maintaining the ceane.

October to June: This includes the period of tying down the cattle and rotating them over the agricultural fields. The standard practice is to tie down only some of the animals as they return in the evening. Those tied down are primarily the lead animals of the herd and those that may be especially difficult to handle. Oxen and bulls are placed on the outer edges of the herd to protect it from night attacks by predators. The animals are tied around the horns with baobab rope made in the household. The other end of the rope is attached to a hooked stake driven into the ground with a wooden mallet. An alternative way to keep the animal in place is to tie two animals to a large heavy log. Calves are separated from their dams and kept in a small thorn bush corral in the middle of the herd.

The head of household uses this time to determine the status of the herd under his authority. He counts his cattle and makes note of missing animals. If an animal is missing for more than three days a search may be initiated to find it. Young animals that are particularly difficult to handle are tamed by roping them to a long stick 3 to 4 centimeters in diameter. The short baobab bark rope and its trailing stick make catching the animal easier. The size and weight of the stick depend on how much the animal needs to be subdued.

Locally made baobab rope, an axe, and a one-piece wooden mallet are the basic tools used for tying down the animals. Long heavy logs, and shorter, lighter sticks to tame animals are obtained from the bush. This task is usually done by the head of household with the help of boys and young men. It is done at the same time as the evening milking. For a herd of a hundred animals less than an hour is spent tying down about twenty head,and corralling the young calves. The release of animals in the morning takes even less time. After the milking is finished and the animals have been freed from their tethers, they are herded by young boys in the general direction chosen by the head household. Cattle are herded for a mile or so and then left on their own.

Time spent milking depends on the season and the number of calves in a herd. Most calvings occur from March to August. During this time a cow about to calf may be separated from the herd and kept close to the village, however this the exception rather than the rule. It is quite unusual to see special attention given to animals other than horses. Milking starts about a week after the birth of the calf and continues for two years whenever there is enough milk for the calves and human consumption. With the onset of the dry season the amount of milk obtained for human consumption is at least halved. In the Sinthiou Fissa and Ololdou zones where transhumance is made necessary by the lack of water, no milk is available during that month.

To bring the milk down the calf is brought to its dam and allowed to start suckling. It is then removed and tied with a short baobab rope to the cow's haunches. The calf may be released briefly if milking is difficult and once more tied until the milking is finished. The calf is then released. The youngest calves are placed in the thorn bush corral and released only when the herd is well on its way. Calves then stay near the village without supervision until the return of the herd. To prevent two year-old calves from suckling when with the herd, several sticks with very sharp ends are attached to the calf's muzzle. This barbed device makes it virtually impossible for the calf to approach the cow's udder. Milking is usually done by young men and boys. However in the rainy season, when milk is abundant, young women also milk cows. Three persons can milk fifteen to twenty cows in less than an hour.

2.6.1.1.1. Transhumance. This applies particularly to the villages that are east of the escarpment in the Sinthiou Fissa and Ololdou zones. In some villages the entire family and herd migrate to another village for the duration of the dry season. This is the case for the village of Sira Hamadi Bocar Kane, in the Ololdou Zone, where three families migrate to other villages where water is more readily available. These villages are Bema, Kadiel, and the small town of Gabou. All are located along the Bakel to Kidira road and and have more reliable access to water. Gabou in particular sees an important increase in

population during the dry season as people and herds come there (ceanes can be sucessfully dug around Gabou).

In the Sinthiou Fissa Zone there are two different patterns of transhumance. Certain villages along the escarpment (Birfal, Gourel Maman Ndieye, and Waly Diala), have a two-step transhumance. The first move is to Ourousoulé as soon as sources of groundwater dry up. The one good well in Ourousoulé then becomes used twenty-four hours a day; it takes longer to recharge and causes delays in watering herds. This sets off a second transhumance towards the Falémé.

For other villages in the Sinthiou Fissa Zone, like Arigabo where water has to be hauled in by horse cart every day during the dry season, the herds are sent to the Falémé (in some cases to the other side of the Falémé into Mali). The rationale for the transhumance is access to water rather than the lack of rangeland for the animals. In the Sinthiou Fissa Zone the village of Belle has a well with a diesel pump; some villages near Belle take advantage of this but for households with large herds and hired herders, it is less costly to send them on transhumance.

August to September setting of bush fires: This is not a recognized task; however, it takes place with some regularity and though not discussed openly, it is recognized as associated with the care of of one's herd. No one admits setting bush fires; it does not appear that any particular individual with experience in setting such fires will assume responsibility. Fires are set by individual herders as they see a need (to improve the quality of the range, according to some interviews).

August to September salt supplement for cattle: During the early rainy season most herds receive a salt supplement. A small pit is dug near the village and filled with water, rock salt is added, and animals are allowed in.

October to November bush camp season: During this period cattle are kept away from the village. Hired herders are accompanied by young boys from the household who return to the village every day with milk from the herd, and take back meals prepared for themselves and the herder.

During much of the dry season, men collect strips of bark from the baobab tree and weave them into various lengths of rope. Large strips of bark are slit and briefly soaked in water if they are too stiff for hand weaving. The ropes used to tie down animals are woven with a built-in slip knot. Much of the rope weaving is done in the village square by men seated on a shaded platform (tchially) used for small group meetings and conversation.

2.6.1.1.2. Operating costs. Expenditures for herd management consist primarily of herders' salaries. A hired herder is paid in cash rather than in-kind. A herder earns

approximately 7,500 CFA per month. If he hired for a six-month period during the rainy season, he receives about 50,000 CFA in total. Other costs are associated with the maintenance of the herder. To some extent the head of household is expected to give him a certain amount of grain and sugar. Herders come from the Boundou or the Perlo, and most are Peuhl rather than Toucouleur.

The herder's salary is determined by the job and not by the size of the herd. A village chief answered the question as to whether a larger herd required more payment than a smaller one by saying "we all go to the bush." The herder is not expected to do all the work by himself. He can be assisted by the sons and brothers of the head of household. This is particularly true for major tasks like watering the animals and milking, as well as the occasional marking and castration. The herder is not given specific instructions concerning which pasture to use when animals are kept near the village. When the herd is sent on transhumance however, specific instructions are given on the watering points he should use.

Male members of the family who have animals in the herd are expected to contribute money to cover their share of expenses. Women with animals in the herd are not expected to pay in cash. A head of household described the system as follows: "if a woman has animals in the herd and her cows have four male calves, the head of household may take two of these as her share of operating costs."

2.6.1.1.3. Castration. As a head of household said, "without castration there is no money." Castration is done for the following reasons. In order to space bulls and always have one that is "ready," the recommended period between bulls is three years. This minimizes fights between bulls. In selecting those bulls to be kept for reproduction, the herder must keep several criteria in mind, i.e., whether it is of good breeding stock; whether it issued from a cow with a good milk supply; and whether the age spacing with other bulls in the herd is adequate.

2.7. PROJECT INTERVENTIONS

Project interventions have necessarily been focussed on several distinct areas, but the assessment of their net impacts is complicated by strong interactions between interventions, and the fact that some secondary benefits have in fact been more substantial than gains from primarily intended purposes. One should also be careful to distinguish between the technical appropriateness of interventions and their delivery or extension.

Technical interventions reviewed here include access roads and firebreaks, fire towers, ponds, the construction of the Mbaniou base, the digging or repair of village wells, and the design of a range management plan. Extension-type interventions consisted mostly of livestock health services, functional literacy in Pulaar, home economics and child health monitoring by the Maison Familiale Rurale, of Ndia, the livestock marketing and supplemental feeding programs.

2.7.1. Roads and Firebreaks

Roads were first built in the area (mostly in the Mbaniou zone) to allow heavy construction equipment access to the pond sites. The term "roads" here refers to graded tracks usable at all times but the height of the rainy season. Access roads were widened and the network extended to provide a total of 185 km of seven-meter wide firebreaks, suitable for comfortable travel by project and private vehicles. In addition, three fire towers were built in the project's first phase, as part of the overall firefighting plan.

Comparisons of overall yearly rangeland burns in the mid-1970s (before construction of firebreaks), and of the present extent of burns, as well as ongoing observation during the project life, indicate that neither the extensive firefighting plan, nor the firebreaks themselves have had a noticeable impact on annual burning. The fire towers have not been used, populations have not mobilized to fight fires -- except when cultivated fields and villages were actually threatened. The effectiveness of firebreaks has proved to be minimal, because of the orientation of prevailing winds, the narrowness of firebreaks, and very fast vegetation regrowth. All these problems have been explained in detail in previous work (inter alia, Legast, 1980), as well as in the Soil and Water Engineering, and Range Management reports. At the same time, the education effort designed to raise consciousness in the population's minds of the need for better bush fire management does not yet seem to have made much of an impact.

The basic problem is that total fire management in the area is technically possible only at costs entirely out of proportion with the benefits one would derive from protecting vast expanses of little used rangeland from fire. The only cost-effective way to deal with fires in vast low-productivity areas is fire prevention rather than firefighting. However, this requires a difficult and long-term effort of dialogue and education with local populations. Fires will always occur in the project area, especially since occasional burning at the right time of year is beneficial to rangelands. Technical approaches designed to control fires mostly set by people appear doomed to failure.

This said, it turns out that one of the most important aspects of project interventions is the impact that the establishment of this network of roads had on the area. Previously,

this part of Senegal was considered one of the most isolated and inaccessible. The only means of communication available before were sinuous, narrow cart trails. Roads have allowed villages in the area to become integrated into the local administration. They are used by project staff who have regularly scheduled rounds in the area. With better accessibility, traffic from government agencies and political parties has increased. Some private transporters have also started to penetrate the area. Villagers themselves remark on their new roads. They see it as an important improvement of their area.

2.7.2. Ponds

The water catchment ponds built by the project have also had an important impact. The fact that they retain water until January or February and are spread throughout the area enables herders to use range that would not have otherwise been accessible. Ponds also push back the time when men must draw water for their cattle. These benefits are well recognized among populations and villages who do not have a pond in close proximity are constantly petitioning the project for pond construction in their area.

In spite of this, long-term benefits from ponds are quite limited. Because of serious infiltration problems (described in detail in the Soil and Water Engineering report), ponds retain water for only a short period of time. Any benefits to cattle up to mid-January, for example, have disappeared by the end of the dry season, and relief on denuded areas around villages is too brief to make an impact on the continuing process of degradation. Furthermore, the current design of ponds requires some regular maintenance: removing excess accumulations of silt, and controlling slope erosion and evaporation by revegetation of slopes, building dikes, etc. Nothing in the project's experience suggests that local populations have either the means or the incentive to take upon these tasks.

The Base at Mbaniou: Many development professionals who have worked on and appraised livestock projects have come to the conclusion that excess physical infrastructure is the chief reason why almost none are financially or economically viable. The basic reasoning is that the very nature of the resources involved makes it extremely difficult to show tangible results of interventions directly aimed at range and animals. The common reaction is to set up highly visible infrastructure (e.g., firebreaks, wells, corrals, fences, administrative buildings and so forth). In this particular case, however, the complete absence of any other infrastructure in the project area justifies such interventions as road building and the establishment of a technical base at Mbaniou, because of the many ancillary benefits from this infrastructure.

The construction of the Mbaniou base with its houses, classroom buildings, offices, storerooms, and garage, each provided with electricity and running water, has had this

type of impact on the area. The establishment of such a base to permit the outposting of veterinary staff has been a success. Because of the precedent set at the base, veterinary staff were assigned to small villages throughout the project zone.

The base also exerted a very strong magnet effect by bringing other government projects to the area. For instance, the base offers housing with a relatively high level of comfort, electricity five to six hours a day, and running water. The Ministry of Education has been able to send a teacher, who started the first Francophone school in the zone. During the school year, 36 children were enrolled, coming from six neighboring villages; 12 of the students were girls.

The Bakel health project also has taken advantage of the physical facilities at the base and there is now medical personnel in the area for the first time.

2.7.3. Livestock Extension Services

Another successful intervention has been the provision of veterinary services in the project area. The outposting of ATEs (Agents Techniques d'Elevage) at the Mbaniou base and in area villages has made it possible intervene almost immediately in response to outbreaks of contagious bovine diseases. On several such occasions the project was notified the same day; in the days that followed vaccine was brought in, and the threat of an epidemic contained.

The fact that some ATEs live in the villages and have a regular visiting schedule permits herders to consult with them, obtain advice and make them aware of any outbreaks of disease among their animals. It is our feeling that observed gains in morbidity and mortality of livestock are directly related to this particular approach of animal health extension services.

To improve the condition of cattle, especially of cows which dropped calves just before the rains, the project has relied on ATEs to encourage herders to buy and use cotton seed as a supplementary feed. There is evidence that in larger villages with important concentrations of animals, the supplemental feeding program has been adopted by some herd owners, although no priority in supplementary feeding seems to be given to lactating cows, as was suggested in extension meetings.

Our survey of inventory changes in livestock herds included prices received for animals sold; these were compared to baseline data collected eight years previously. For cattle, comparisons of weighted average sales prices suggest an increase in prices received of about 30 percent; for goats, the increase is on the order of 20 percent. Baseline data on sheep prices are unfortunately not available, but considering the average 1984 sale price of sheep (over 13,000 CFA Francs), the increase in price received by local populations must have been much higher than for goats.

The marketing program was established by project staff to give herders access to an additional marketing outlet, thereby promoting competition with other buyers, and hopefully maximizing the economic benefits derived by owners from animal sales. In the beginning, a contract was signed with SERAS, a public society in charge of livestock and meat marketing. Animals were bought on a live-weight basis, and transported to Dakar. Selling animals from the Boundou on the Dakar market was -- and remains -- a rational approach, since the price of meat at the retail level is higher in Dakar than anywhere else in Senegal. It turned out, however, that because of its costs and fees structure, SERAS could not really pay more on a live-weight basis than the prevailing rate among traditional buyers, and this approach was discontinued. It was then suggested that the project buy animals, transport them to Dakar with its own truck, and sell them to private traders on the capital's livestock market. However, it soon became apparent that this required a knowledge of the industry and professional connections -- in addition to some sharp management and business skills -- that no one on the project staff possessed. Nevertheless, continued improvement of project marketing activities should be sought. Currently, cattle are bought from herders and sold on the Bakel market, partly under pressure from local authorities who are having difficulties convincing private operators to butcher animals, given the official retail price of meat in the city. Supplying cattle to the city of Bakel therefore resembles more a public service than efforts to maximize the benefits derived by herders from their animals. As far as cattle are concerned, the option of helping organize shipments from the project area to more promising regional markets like Goudiry and Tambacounda must be seriously explored. Also worthy of additional involvement is the area of small ruminant marketing -- especially sheep. Project marketing activities dealing with sheep have excellent potential, especially as they may relate to the sharp annual rise in demand for Moslem holidays.

2.7.4. Other Extension Services

One must first recognize that general extension activities in the project's more recent phase (after the 1980 redesign) have taken on a relatively bold new orientation, and have been much more successful than anything attempted previously. Prior to 1980, the approach had been to provide livestock health extension through livestock agents working out of the city of Bakel, which meant that any visit to the project area turned into a minor expedition. Other extension services (sensitizing populations about project activities and objectives, education, home economics, etc.) were handled by Promotion Humaine agents, most of whom could not speak Pulaar, and had no technical knowledge of the local agropastoral system. In addition, technical staff in charge of livestock extension

and Promotion Humaine agents answered to different administrations, and neither worked together nor coordinated their activities.

The project administration deserves very high marks for restructuring extension services along lines much more suitable to local conditions and more conducive to the establishment of working rapport with the populations. In the first place, the technical and extension field staffs were moved to the Mbaniou base, located in the project zone. Secondly, livestock and other extension services are handled by Pulaar-speaking agents either assigned to various villages, or operating out of the Mbaniou base. By working so much closer to project populations, extension staff have gained a greater degree of trust on the part of villagers, and a much better perception of day-to-day problems facing them.

2.7.4.1. Pulaar Literacy

One of the most successful project interventions has been the Pulaar literacy program. The project recruited and trained fluent Pulaar speakers to teach literacy in certain villages of the project area. The teachers, or AVEs (Agents Vulgarisateurs d'Elevage), are based in villages throughout the project area. From there, they have a regular schedule of classes in nearby communities. Villagers are expected to provide a classroom for the students. Most are crudely built structures that provide shaded space to hold classes.

The classes are extremely well received with a high level of attendance. When visiting a village with a literacy program, one is struck by the amount of graffiti on the walls of houses, done either in chalk or charcoal. These are done by young students having learned to write, and possessed with the need to do so. Any vehicle arriving in the village covered with dust is soon used as a blackboard. Upon arrival, it is common to have young students proudly place in your hands scraps of paper with writing in Pulaar. In one compound a new bench had been built. The split wood logs, fresh and almost white, had been almost entirely covered with writing in Pulaar.

The Pulaar literacy program lasts three years. After the third and final year of Pulaar classes, a Francophone school was opened in the Mbaniou Zone. The school was well attended and students were well prepared undoubtedly because most had already attained a certain level of literacy in Pulaar.

The literacy classes, open to children as well as adults, are conducted around useful themes. For instance: how to recognize illness in a cow, ways a good herder should look after his cattle, or feces-borne diseases and village sanitation.

2.7.4.2. Maison Familiale of Ndia

The village of Ndia hosts a Maison Familiale (rural family extension center), whose staff works in several villages of the Mbaniou Zone. They have been regularly monitoring the weight and growth of infants. With the help of the Maison Familiale, the villages of Ndia and Mbaniou have been able to obtain milling machines which are important time and labor savers for women.

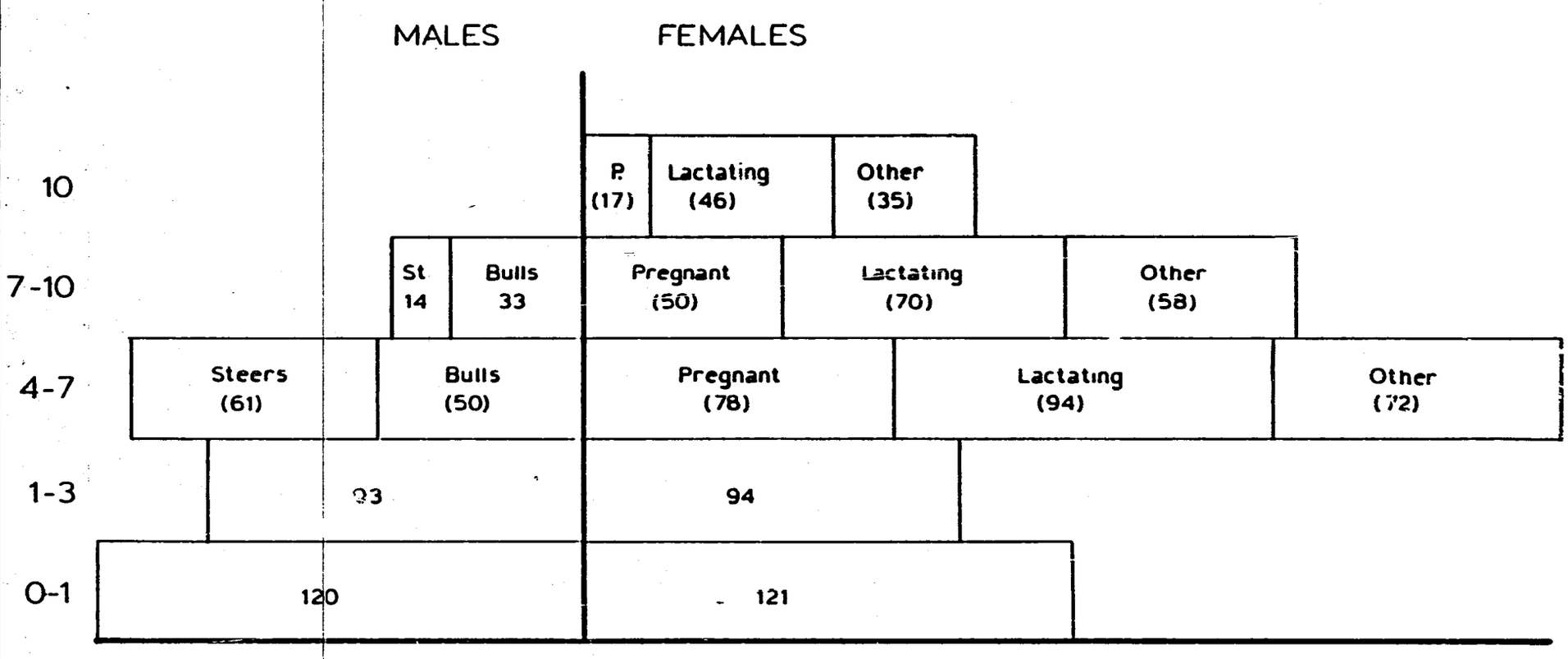


Figure 2.5. Age/Sex Distribution of Cattle Herds; All Zones

3. MEASURES OF INCOME AND WELL-BEING

There are many possible ways to measure rural well-being; in this case, we opted to include key cash inflows from grain and cattle sales (agricultural income), and receipts from local nonagricultural activities and remittances from migrants. In addition, the levels of food purchases and of actual food consumption over time for each surveyed family provide reliable indicators of food self-sufficiency and of food intake.

3.1. RURAL INCOME AND FOOD CONSUMPTION

3.1.1. Agricultural Income

3.1.1.1. Grain Sales

There has traditionally been a strong grain market in the area, especially for sorghum. Grain is generally sold at a rate above the official price. There seem to be two periods with greater activity in grain sales; upon harvest, when the head of household can assess the grain on hand, and prior to the rainy season, when he has taken stock of his reserves and can count on new production.

Prior to the 1983 harvest, 27 metric tons of sorghum were imported by the project and sold in the Mbaniou Zone at 80 CFA Francs per kilogram, 11 CFA Francs above the purchase price (Diaw, 1983). There were only cash transactions, and each head of household actively involved was limited to 200 kilograms of grain. The total cash outlay in the Mbaniou Zone for the 27 tons of sorghum was 2,160,000 CFA Francs. This points out two very important facts. First, there was no grain surplus in 1983, and second, there was cash available to compensate for the subsistence deficit.

Data on agricultural sales collected from each of the 120 surveyed households for over a year confirm this. Table 3.1. clearly shows the relatively insignificant importance of millet, sorghum and peanut sales in total agricultural marketing for all zones (just over three percent of total value). The bulk of agricultural income undoubtedly comes from livestock sales, and this money is primarily spent on grain purchases for millet, sorghum and maize from outside the region.

3.1.1.2. Cattle sales

Livestock marketing in the project area involves two parallel markets: (a) the traditional system by which people sell animals to travelling collectors (Dioula), or take animals themselves to a small regional market; and (b) marketing activities organized by

the project. Several surveys, based on price comparisons between animals purchased by Dioula in the area and levels of transactions on nearby regional markets (Bakel, Tambacounda) suggest that the traditional marketing system is tolerably competitive and efficient. In fact, in the case of cattle, the project marketing program has not been able to offer prices substantially higher than those prevailing in the traditional system.

TABLE 3.1.

MAIN AGRICULTURAL SALES, ALL ZONES

Product	Gross Income	%	$\bar{X}$ Unit Price
Cattle	13,114,580	80.1	49,000
Goats	1,521,352	9.4	7,760
Sheep	956,160	5.9	13,280
Millet	434,544	2.7	
Horses	65,000	.4	65,000
Peanuts	61,250	.3	61
Chickens	34,008	.2	872
Donkeys	30,000	.2	10,000
Sorghum	11,100	.1	
Total	16,227,994	100	

As we could see from Table 3.1., livestock makes up over 95% of agricultural sales. The second noteworthy point is that these sales nonetheless represent a very low level of offtake, considering that herds are not in a cycle of fast expansion. The estimated offtake rate for cattle is on the order of 6 to 8%, compared to a biological potential equilibrium offtake rate of over 10% in similar traditional systems. The observed structure of local herds, however, indicates maximum destocking, and even replacement of lost females through purchases; the conclusion is that calf mortality levels have remained high, and constitute the major obstacle to increased sales, rather than herd owners' attitudes or other factors. The same applies even more in the case of small ruminants, and for the same reasons.

Table 3.2. breaks down agricultural sales, receipts and average unit price by zone. Cattle sales in each zone reflect their respective herd holdings; the high revenues from goat sales in the Ololdou zone springs from that area's lesser endowment in grazable range, and the local emphasis on small ruminants. Because of higher cattle marketing,

TABLE 3.2.

AGRICULTURAL PRODUCTS SOLD, RECEIPTS AND AVERAGE UNIT PRICE, BY ZONE
(CFA Francs)

Mbaniou (50 HH)			Sinthiou Fissa (40 HH)			Ololdou (30 HH)		
Item	Sales	X Rice	Item	Sales	X Rice	Item	Sales	X Rice
Cattle (145)	7,451,985	51,400	Cattle (52)	2,537,496	48,800	Cattle (71)	3,124,994	44,000
Sheep (36)	450,756	12,500	Millet	338,000		Goats (100)	836,050	8,360
Goats (57)	404,244	7,100	Goats (39)	280,995	6,864	Sheep (25)	307,900	12,300
Millet	96,543	57/kg?	Sheep (11)	197,505	17,955	Donkeys (1)	10,000	
			Horse	65,000				
Chickens (19)	14,550	766	Peanuts	58,250		Chickens (1)	400	
Sorghum (6)	11,100		Donkeys (2)	20,000				
Peanuts (1)	3,000		Chickens (19)	19,049	1,000			
Total	8,432,178		Total	3,516,295		Total	3,493,294	
X/household	168,643			87,907			114,776	

NOTE: Numbers in parentheses refer to the absolute frequency of sales.

average agricultural sales per household were highest in the Mbaniou zone, the Ololdou and Sinthiou Fissa zones being second and third, respectively.

3.1.2. Nonagricultural Income

3.1.2.1. Small shops

The project area lacks either permanent or rotating produce and dry goods markets. The only permanent markets are in the major towns and administrative centers of Bakel, Kidira and Goudiry. There is, however, significant small-scale economic activity in villages. Even the smallest village in the area has what could loosely be called, a shop. These are simpler versions of the small neighborhood stores found in most small towns of Senegal. Stock and supply are limited and sporadic as the shopkeeper rarely has a chance to make business trips to Bakel, Kidira or Goudiry.

In some villages of 150 inhabitants, three small shops offer sporadically a variable amount of stock (see Table 3.3.). The investment needed for such a business is limited. One shopkeeper said she bought her initial stock with 25,000 CFA Francs sent by her migrant brother. The investment consisted of 5 gross of sugar, 15 liters of oil, a large sack of hardtack biscuits, soap blueing, and tea.

The same shopkeeper had money on hand to replenish her stock, but when interviewed in February 1983, she was trading more goods for sorghum than for cash. At the time, there were seven sacks of sorghum in the room used as a shop. It was traded at the prevailing market rate, above the official price. Though this shop was exceptionally well-stocked and successful, it is typical of others in the area. They are generally run by women and initially capitalized by remittances. Whenever an item is not available, one is sent to the closest other shop.

3.1.2.2. Crafts

Most villages have craftsmen: smiths, who make and sell axes, and traditional farm tools; and woodcarvers who make bowls for milking, stools, mortars and pestles, items essential to every household. Some villages have matmakers and weavers, but these specialized skills are rare in the project area. The items produced are either sold locally or sold to retailers in nearby towns.

Some village also have other skilled craftsmen like traditional adobe house builders. The going rate for a well-built round adobe house is 5,000 CFA Francs; a square house cost 2,000 CFA Francs more. The construction cost covers only the work by the mason on the walls -- the owner is left to timber and thatch the roof.

TABLE 3.3.

SAMPLE OF GOODS AND HOW THEY ARE RETAILED IN A SMALL VILLAGE SHOP

Cube sugar	Sold by the piece or box
Sugar candy	Sold by the piece
Cigarettes	Camelia sold by the cigarette or the pack
Matches	
Blueing	In small packets
Chinese green tea	Sold by the shot glass
Hardtack biscuits	Sold by small bag
Fried fish	
Soap	Sold by the cake or half a cake (savon de Marseille type)
Rice	
Vegetable oil	
Sorghum	
Onions	
Canned milk (gloria)	By the small can during the dry season
Maggi cubes	Spiced bouillon cubes
Vinegar	
Batteries, D Cells	
Light bulbs for flash lights	
Nescafe	

Large adobe or cement block structures are built by masons brought into the area on contract. They charge 200,000 to 400,000 CFA Francs for the construction of a tin-roofed house, depending on size and number of rooms. Construction generally starts during the dry season in hopes of completing the structure before the rains. The mason brings assistants and apprentices, while the owner provides materials like sand, cement, beams, roofing material, water, and adobe or cement blocks.

Several villages have specialized craftsmen in semipermanent residence. In such cases they reside in the compound of the village chief, where they practice their craft. Having a silversmith or a tailor in residence, as do two villages, imparts a certain prestige to the community.

3.1.2.3. Bread ovens

In the Boundou there seems to be a certain taste for French bread made of wheat flour baked in adobe ovens. Villages who have and maintain a functioning oven are proud of it, and people come from neighboring villages to buy bread. Ovens do not operate

regularly. There are two reasons for this: supply of flour is uneven, and bakers go from village to village looking for better opportunities because owners underpay them. In one case the village chief owning the oven was said to offer the baker three loaves of bread for his day's work. At 70 CFA Francs a loaf, this could not be considered much of a salary by the baker. In another case the sporadic operation of the oven was taken over by young boys attending Koranic studies.

3.1.2.4. Other economic activities

In several villages hunters sell meat (generally koba or gazelle) to other villagers. On an irregular basis large or small ruminants are sometimes also butchered at the village, especially around feast days, when all the meat is likely to be sold. In one village near the Dakar-Bamako railroad line, several cows were run down by the train. Several animals could be slaughtered according to religious prescriptions, and much meat was available at very low prices for a brief period. In one village an enterprising man carries a large plastic bag of hard sugar candy which he sells to many children and adults.

3.1.2.5. Travelling merchants

Villages in the project zone are constantly visited by itinerant salesmen. Cloth salesmen are seen on a regular basis, especially after the harvest, and before feast days. Travelling hardware salesmen offer used parts to repair horse carts and agricultural equipment. One group of women was identified as Fulani from Niger, selling traditional medicines and herbs. At times, specialists in male circumcision and female excision visit the villages making their services available for 250 CFA Francs per operation. Cola nut salesmen often pass through the area, resupplying local shops.

Itinerant musicians stay for a few days in some villages. Earnings for an evening's singing by two musicians may be between 10000 and 15000 CFA Francs. A visiting genealogical griot may leave after two days of work praising a family and other villagers with a four-year old ox, a small piece of gold, several sheep, pieces of cloth, and cash.

3.1.2.6. Economic activities of women

The largest scale of economic activity for women in the project area is their operation of small village shops, but they are also involved in other, more traditional activities.

Women are responsible for, and own, small ruminants. They derive an income from the sale of their animals. As for cattle, sales of small ruminants are generally negotiated through the head of household or some other male member of the compound.

Several villages in the area have women who belong to the potter caste. They make large and small water jars, open water pots, and couscous steamers. Their products are sold locally or in the major towns of the area. Prices are about a 750 CFA Francs for a water jar, and 300 CFA Francs for a small jug. Village women sometimes prepare beignets, a wheat-based fritter or doughnut. These are sold in the morning for breakfast at 5 CFA Francs a piece. Villagers usually know who prepares beignets, and children are sent to buy some.

Women may also sell what they have gathered or processed. Examples include the sale of tamarind fruit or of crushed dry baobab leaves, an essential condiment in the preparation of couscous.

3.1.3. Food Purchases

Tables 3.4. through 3.6. present a list of the main food items purchased by surveyed households in each zone, from May 1983 for a period of about one year. The information, collected on a biweekly basis included a list of the purchased items, quantity bought, unit and total cost, and expected duration of this supply (see questionnaire form 7 in the Appendix).

The total amount spent on food purchases was highest in the Ololdou zone; food purchases per household were equivalent, on the average, to 104,472 CFA Francs annually. In the Sinthiou Fissa zone, the total amount spent on food purchases was equivalent to about 64,455 CFA Francs; finally, the lowest food purchases of the Mbaniou zone amounted to an average 27,438 CFA Francs per household per year. In spite of marked differences in the level of spending, its distribution over the range of items across zones is very similar. Five or six basic food items account everywhere for over 80 percent of purchases; in decreasing order of importance: millet, rice, peanuts, sugar, oil and dry fish. Not surprisingly, these all are known as primary ingredients in the preparation of most common dishes consumed in the area.

The remainder of the purchased items are also typical of the kinds of foods consumed in the Boundou; the very limited amounts spent on animal protein derived from red and white meat are mostly offset by consumption of peanuts and dry fish in sauces, and by occasional slaughter of small stock raised by the family. One should note also the absence of reported transactions in sorghum and maize. As a general rule, households surveyed in the three zones grow mostly sorghum, then maize, and millet; as we can see from the list and quantities of agricultural products sold by each zone, very little sorghum or maize is marketed by these farmers. The deficit in home cereal production is therefore made up mostly by millet and rice purchases, rather than through the acquisition of additional sorghum or maize.

TABLE 3.4.

FOOD PURCHASES, MBANIOU ZONE
(CFA Francs)

Item	Total Spent	% of Total
Millet	588,781	43
Rice	240,199	17.5
Peanuts	178,517	13
Sugar	126,655	9.2
Oil	97,579	7.1
Dry fish	43,750	3.2
Biscuits	25,264	1.8
Onions	13,624	1
Coffee	9,945	.7
Tomato paste	8,400	1
Salt	8,110	1
Beef	6,330	1
Bread	4,995	1
Deer meat	3,550	1
Hot pepper	2,720	1
Cola nuts	2,425	1
Cowpeas	1,800	1
Concentrated sweetened milk	1,750	1
Other items	7,503	1
Total	1,371,897	

TABLE 3.5.

FOOD PURCHASES, SINTHIOU FISSA ZONE
(CFA Francs)

Item	Total Spent	% of Total
Millet	535,750	20.8
Rice	493,792	19.15
Sugar	359,648	14
Peanuts	349,741	13.5
Oil	223,876	8.7
Dry fish	219,949	8.5
Coffee	74,360	2.9
Salt	43,305	1.7
Beef	40,750	1.6
Bread	27,359	1.1
Cola nut	22,095	.85
Tomato paste	18,660	1
Lamb	17,499	1
Biscuits	17,120	1
Bouillon cubes	10,825	1
Onions	10,080	1
Fritters	6,420	1
Concentrated milk	6,140	1
Powdered milk	2,700	1
Other items	98,156	3.8
Total	2,578,225	

TABLE 3.6.

FOOD PURCHASES, OLOLDOU ZONE
(CFA Francs)

Item	Total Spent	% of Total
Millet	981,001	31.3
Rice	737,441	23.5
Peanuts	358,124	11.4
Sugar	270,385	8.6
Oil	239,564	7.6
Dry fish	175,325	5.6
Corn meal	149,975	4.8
Coffee	62,925	2
Biscuits	35,825	1.1
Salt	30,204	.9
Onions	22,680	1
Tomato paste	15,100	1
Pepper	11,230	1
Beef	8,000	1
Concentrated milk	6,400	1
Tea	5,400	1
Cola nut	4,050	1
Powdered milk	3,980	1
Hot pepper	3,800	1
Lamb	3,500	1
Deer meat	3,000	1
Other items	6,245	1
Total	3,134,154	

3.1.4. Food Consumption

A dietary survey of all surveyed households was conducted for over a year; the basic rationale was that nutritional intake (even simply defined in terms of calories and protein) is a valid and reliable indicator of well-being in rural communities. A team of six women enumerators, Pulaar-speaking and from the larger surrounding region, was hired, trained, equipped and assigned to project villages for this purpose.

Each surveyed household was surveyed for three consecutive days, three times a year. Prepared food was weighed and recorded before cooking, and the number of men, women and children partaking of each meal was noted. Women enumerators were also in charge of collecting from household women information on food purchases.

Given the age/sex structure of the surveyed population, we estimate the weighted average caloric requirement per "fully active" person to be about 2,300 Kilocalories (Kcal) per day (Latham, 1980). Observed levels of food consumption lead to lower estimates of nutritional intake. For the surveyed population as a whole, Table 3.7. shows mean caloric intake to be 1,965 Kcal per person per day. Unadjusted protein intake is higher than the conventional norm of 30 to 35 required grams per person per day, but because of caloric deficiencies, part of it is certainly converted to energy, so that the actual proteic intake is much lower. One should also note that the range of nutritional intake among surveyed families is rather wide. Table 3.8. and Figure 3.1. shows that if the better-off 25% of households consume at least 2,400 Kcal/person/day, the least well nourished 25% of households consume less than 1,431 Kcal/person/day. Although the dietary survey did not include between meal food consumption (which can be quite significant, especially for women and children), the data suggest severe nutritional deficiencies in a relatively important proportion of families.

TABLE 3.7.

FOOD CONSUMPTION SUMMARY STATISTICS; ALL ZONES

	Mean	Stand. dev.	.95 Conf. Interval
Kcal/per/day	1,965	743.6	1,819 - 2,111
Gr. prot/per/day	59.5	22.4	54.1 - 62.9

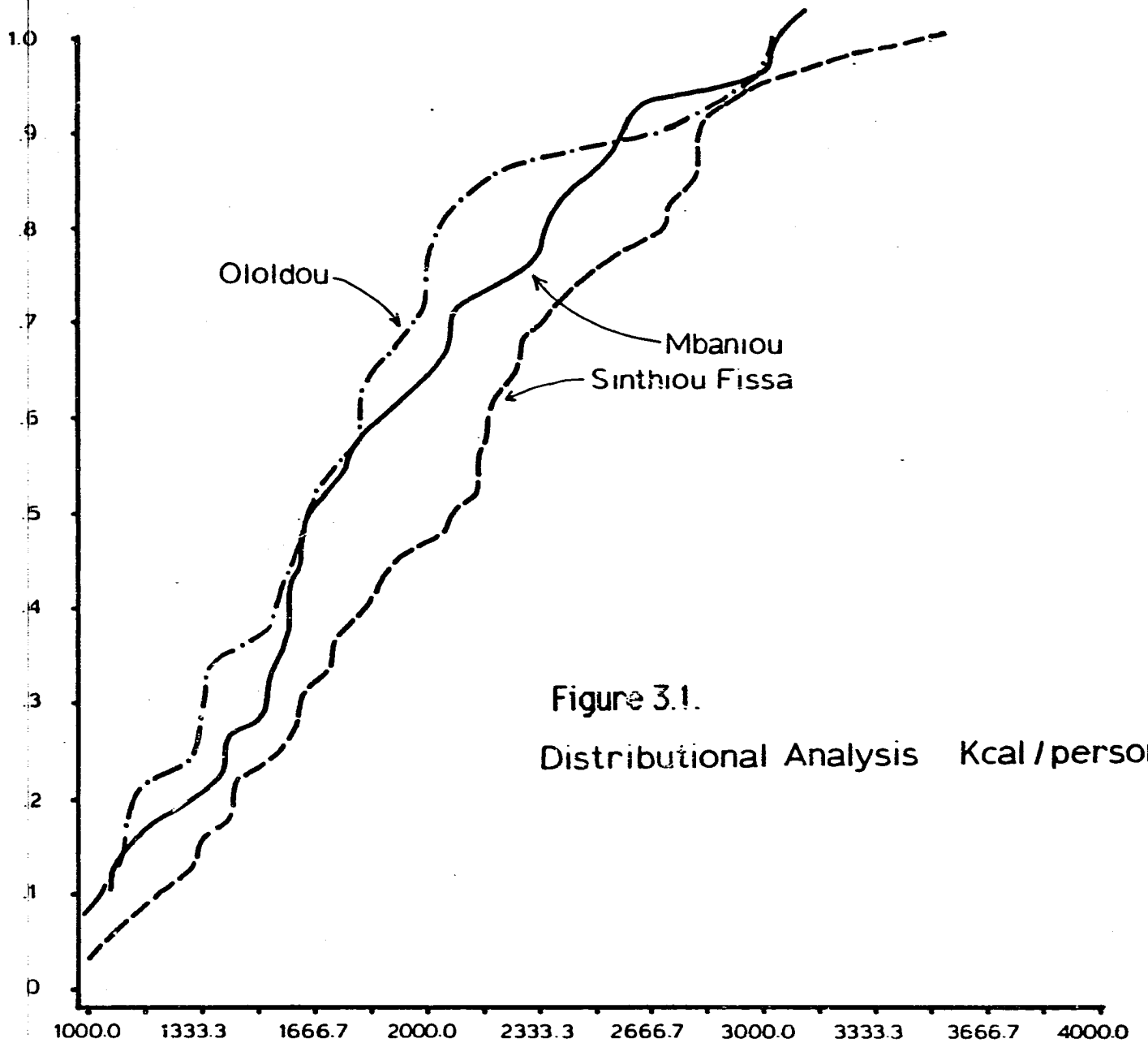


Figure 3.1.

Distributional Analysis Kcal / person / day

TABLE 3.8.

DISTRIBUTIONAL ANALYSIS OF CALORIC AND PROTEIN INTAKE; ALL ZONES

Prob.	Quantile	Conf. Interval (95%)
.25	1,431	1,325 - 1,605
.5	1,860	1,658 - 2,066
.75	2,399	2,203 - 2,733

(Grams/per/day)

Prob.	Quantile	Conf. Interval (95%)
.25	43.9	39.8 - 47.8
.5	55.2	51.4 - 59.9
.75	67.9	65.1 - 79.9

Since dietary intake was followed for over a year, it is possible to examine its evolution over the various seasons. Figures 3.2 through 3.4 show changes in population-wide levels over a year, data points being spaced one fortnight apart. First, since the composition of diet does not change significantly over time, caloric and proteic intake are remarkably similar in trend. Secondly, caloric intake is clearly lower at the end of the dry season, when food stores are exhausted, but at the time of most demanding agricultural labor. There is no doubt that agricultural productivity must suffer from this.

A comparison of mean nutritional intake across zones presented in Table 3.9. reveals significant differences. Lowest caloric and proteic intakes are observed in the Ololdou zone, which has poorer range and agricultural resources than the other two (along with high rates of migration). The Mbaniou zone comes second, with average caloric intake of just under 2,000 Kcal/person/day, close to satisfying requirements. The Sinthiou Fissa zone has slightly higher levels of caloric and protein intakes. Putting together what we know of these three zones leads to these tentative conclusions: average nutritional intakes in the Mbaniou zone are consistent with relatively very low food production on the farm, and lower out-migration, but highest reliance on livestock sales for agricultural income. The Sinthiou Fissa Zone has probably had the highest level of agricultural ouput (it was the only zone selling significant amounts of millet during the year), its lowest livestock sales are offset by the combination of more favorable agricultural conditions (at

Figure 3.2. Calories and Adjusted Protein / Person / Day May 1983-May 1984

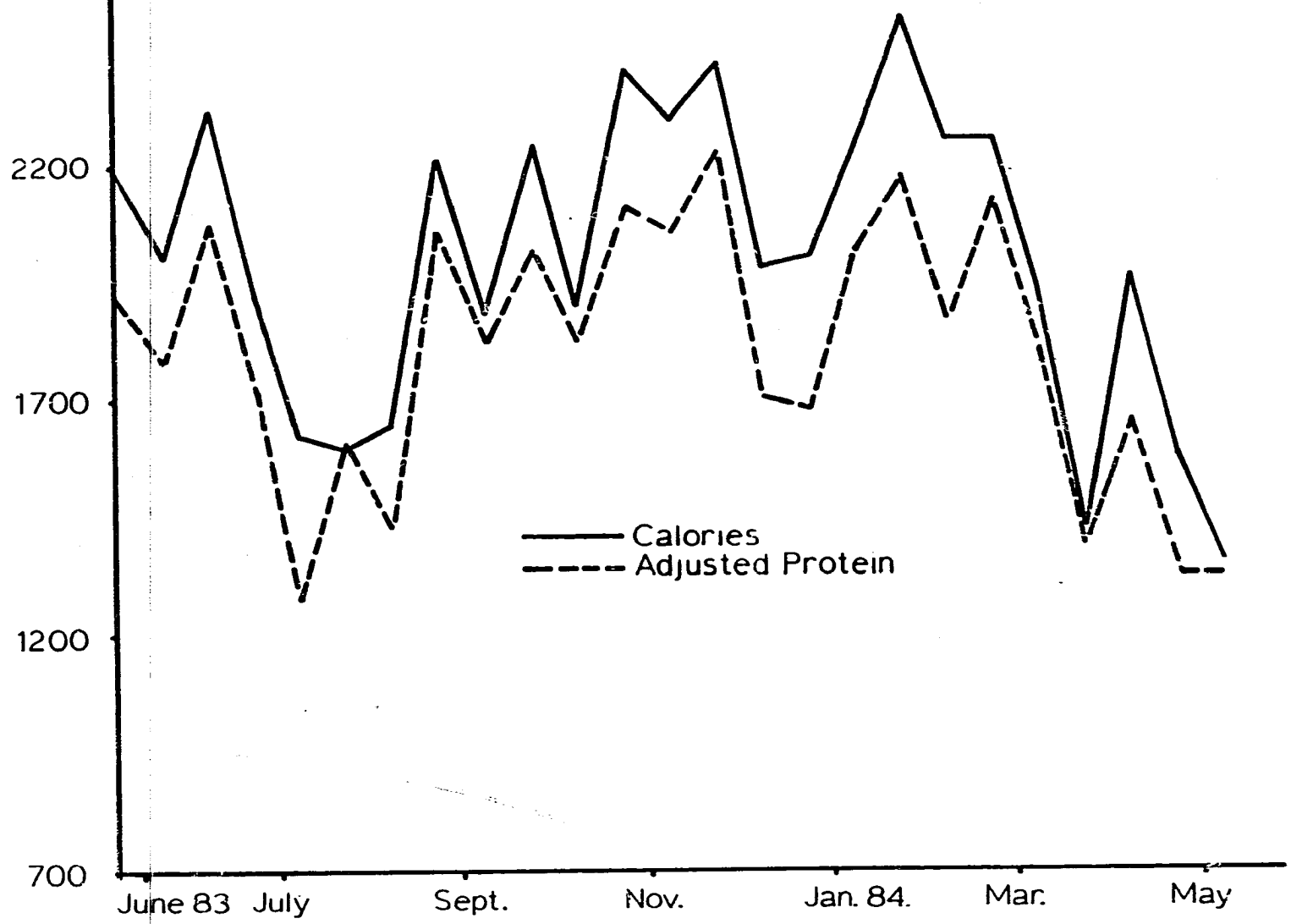


Figure 3.3.

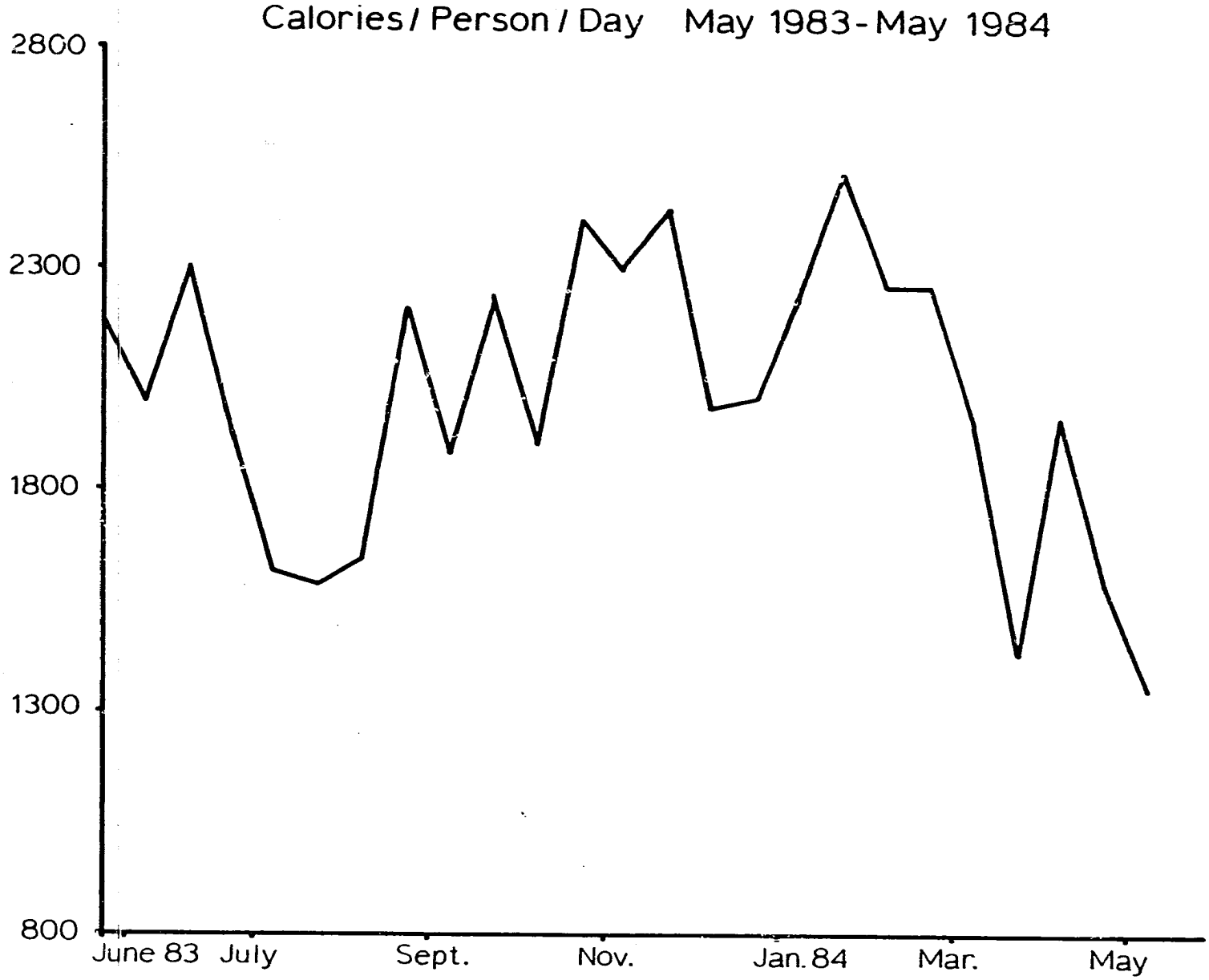

Calories / Person / Day May 1983 - May 1984
2800
2300
1800
1300
800
June 83
July
Sept.
Nov.
Jan. 84
Mar.
May

Figure 3.4. Protein / Person / Day May 1983 - May 1984

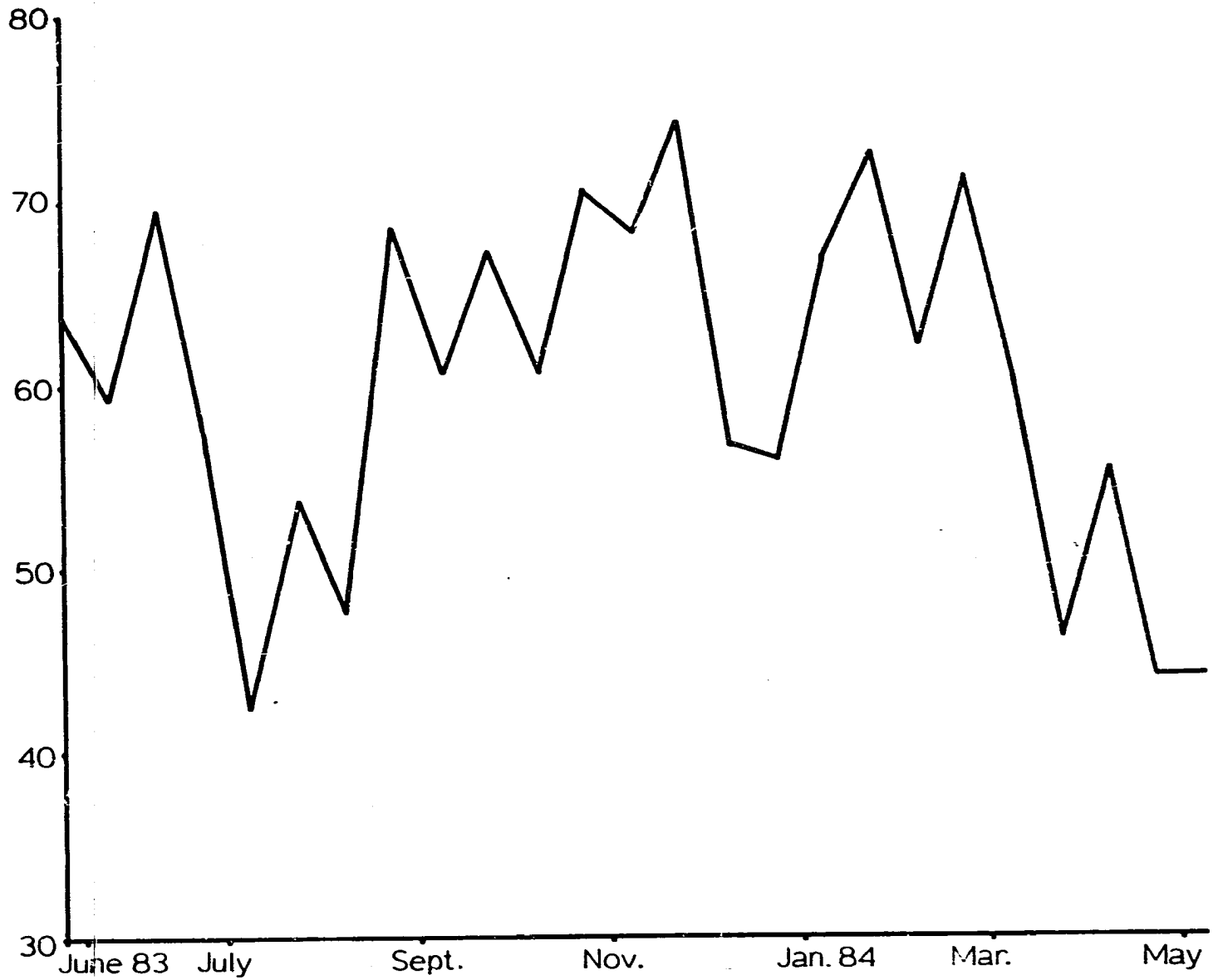


TABLE 3.9.

FOOD CONSUMPTION SUMMARY STATISTICS; BY ZONE

	Mean	Stand. Dev.	95% Conf. Interval
1. Mbaniou			
Kcal/pers./day	1,988	840	1,700 - 2,277
Protein/per/day	59.3	26.3	50.3 - 68.3
2. Sinthiou Fissa			
Kcal/pers./day	2,048	704	1,839 - 2,257
Protein/per/day	61.8	20.5	55.7 - 67.9
3. Ololdou			
Kcal/pers./day	1,743.5	638	1,453 - 2,034
Protein/per/day	50.1	17.5	42.1 - 58

least in 1983-84) and the highest extent of migration. Finally, the Ololdou zone had average livestock sales, but probably the greatest deficit in food production, which was not quite made up by remittances consistent with its second rank in out-migration.

One must note that there is a clear positive relationship between the extent of out-migration and the level of food purchases for surveyed families. The correlation coefficient between the migration index and food purchases is significant at the 95 percent confidence level (see Appendix).

3.2. MIGRATION AND REMITTANCES

3.2.1. Historical Foundation and Background

The contemporary genesis of the Boundou's labor migration in general and to France in particular, lies in the migration pattern of the Soninke of the Goy. The history of labor migration by the Soninke has been well documented by Adrian Adams (1977:48-65). Adams notes that the defeat of the Soninke by the French colonial administration meant that they also lost the control of trade along the Senegal Valley. In order to gain new sources of income, the Soninke worked as stokers on river steamers, eventually moving to ships plying the coast of Africa from St. Louis. During the first World War Soninke

stokers and ship hands were hired on merchant ships going to the ports of Bordeaux and Marseille where the first communities of Soninke labor migrants were established (Adams, 1977:48-65).

The great surge of migration took place in the post-World War II economic boom in Europe, starting in the late 1950s. Small groups of Soninke established in French cities became the essential links in the pattern of migration that evolved throughout the 60s and 70s. In this way, new migrants received help from kinsmen and friends who had preceded them in finding lodging and jobs. Soninke and Toucouleur migrants who had jobs in France financed and organized the migration of their kinsmen. The pattern and routes of migration developed by the Soninke were later followed by the Toucouleur of the Fouta Toro and the Boundou. Naturally, the route and means of travel changed many times to reduce expense and find the easiest entry into France whose borders have not always been open to labor migrants. The establishment of small groups of migrants in French cities of a common ethnic group and from the same region opened the way to the process called chain migration (Duberson, 1975; Kane and Lericollais, 1975).

By the early 1960s residents of the Boundou started their own network of chain migration. By the late 1960s there may have been as many as 250,000 black Africans in France, 20% of whom were Toucouleur (Adams, 1977; N'Diaye, 1970). While this figures is probably inflated by half, the proportion of Toucouleur to Soninke is probably accurate. Migration from the Boundou cannot be compared in numerical importance to the pattern established by the Soninke of the Goy and Guidimaka, or of the Toucouleur of the Fouta Toro. In the Fouta Toro the extent of migration varies greatly ranging from 24 to 47% of the able-bodied male population (Duberson, 1975; Fieloux, 1979). For the Guidimaka the extent of migration is estimated as 10 to 15% of the male population (Bradley, 1977). A recent study done in the Goy showed that 30 to 50% of the able-bodied male population was away on labor migration (Weigel, 1982:24).

3.2.2. Migration from the Project Area

Long-distance labor migration is a major social and economic feature of the project area. Table 3.10. shows that the overall mean number of migrants per household in the project area is 1.5; mean length of stay away from home for migrants who have returned being 5.6 years. The range is quite wide, however; in our sample absences varied from a few weeks to several decades. The mean age of current migrants ranges from 27 to 30 years, according to the zone. The age pyramid in the project villages clearly shows that there are fewer men in their mid-twenties than would be the case without a constant outflow of men due to labor migration.

TABLE 3.10.

OVERALL MIGRATION STATISTICS, BY ZONE

	Mbaniou	Sinthious Fissa	Ololdou
No./Household	1.2	1.7	1.6
Mean Age	30	29	27
Duration of Absence for Former Migrants (yrs.)	5.9	5.85	5.2

Motives for migration, shown in Table 3.11., are clearly wage-employment oriented, whether for current or former migrants.

TABLE 3.11.

MOTIVES FOR MIGRATION

	Current Migrants	Former Migrants
Salaried Work	105	43
Trading	11	1
Schooling	4	-
Other	25	1

Remittances sent by migrants play a major role in the local economy. For example, during an eight-month period from December 1983 to August 1984, six villages in two of the project zones received a little over 9 million CFA Francs (about $22,500) in postal money orders. This is superior to the value of sales of all agricultural products from these villages for the same period. Table 3.12. shows the actual extent of remittances. Among migrants the destination of choice is France with 80 percent of the migrants presently away being there, 1 percent in Senegal and 9 percent in other African countries (for example, Gabon and the Ivory Coast), as we see from Table 3.13.

Since 1974 The French government has attempted to stop labor migrants from non-EEC countries, but they have had trouble stemming the flow of migrants. Our study found that a determined individual with connections in France can eventually find a way, as illustrated by the following example. The smith in one of the project villages was

TABLE 3.12.

REMITTANCES RECEIVED IN SIX VILLAGES FROM DECEMBER 1983 TO JULY 1984

Year	Month	Village	No.	Amount of Mandat
1983	December	A	8	190,000
1984	January	A	2	340,000
1984	February	A	7	833,645
1984	March	A	7	667,560
1984	April	A	8	716,000
1984	May	A	7	495,000
1984	June	A	5	340,000
1984	July	A	8	530,000
Totals for Village		A	50	4,112,205
1983	December	B	3	95,000
1984	January	B	2	30,000
1984	February	B	3	567,000
1984	March	B	3	570,000
1984	April	B	4	165,000
1984	May	B	5	107,500
1984	June	B	4	270,000
1984	July	B	5	247,500
Totals for Village		B	29	2,052,000
1983	December	C	0	
1984	January	C	3	110,000
1984	February	C	0	
1984	March	C	1	250,000
1984	April	C	3	102,000
1984	May	C	0	
1984	June	C	3	72,000
1984	July	C	0	
Totals for Village		C	21	534,000

Year	Month	Village	No.	Amount of Mandat
1983	December	D	4	260,000
1984	January	D	1	100,000
1984	February	D	2	125,000
1984	March	D	7	600,000
1984	April	D	1	50,000
1984	May	D	1	100,000
1984	June	D	1	10,000
1984	July	D	1	100,000
Totals for Village		D	10	1,345,000
1983	December	E	3	225,000
1984	January	E	2	40,000
1984	February	E	2	130,000
1984	March	E	1	75,000
1984	April	E	2	40,000
1984	May	E	4	197,000
1984	June	E	4	136,000
1984	July	E	3	46,000
Totals for Village		E	21	91[illegible],000
1983	December	F	1	20,000
1984	January	F	0	
1984	February	F	0	
1984	March	F	0	
1984	April	F	0	
1984	May	F	1	5,000
1984	June	F	0	
1984	July	F	0	
Totals for Village		F	2	25,000

Total number of remittances received in 6 villages: 130

Total number of CFA remittances received in 6 villages: 8,955,705

Mode of 130 remittances received: 50,000 CFA

determined to go to France during the summer of 1983; this was at at time when the French were attempting to stop migrants from black Africa. A new migrant route had been established by which migrants entered France via Belgium. Everything was ready for the smith's departure when the French government arrested two black Africans crossing the Belgian border without proper papers.

The French government gave this arrest and subsequent repatriation major coverage on Radio France International and encouraged the Senegalese government to do the same. Consequently, for several weeks the main national daily paper and the national and regional radio stations carried newscasts and articles attempting to discourage migrants heading towards France. The smith did not leave at the appointed time but delayed his departure until he received a certificate which his relatives in France had obtained from their local city hall. The certificate attested to the fact that the smith's kinsmen would bear any expenses during his stay in France. Apparently this strategy worked because he left for France and did not return to the Boundou. In some cases the process is much simpler, for instance, brothers trade places.

TABLE 3.13.

DESTINATIONS OF MIGRANTS

	Current Migrants	Former Migrants
France & Other African Nations	118[a]	44
Other Regions of Senegal	14[b]	0
Sénégal Oriental	16[c]	1

NOTES: (a) Including 4 women.
(b) Including 5 women.
(c) Including 12 women.

The cost of migration is high. Approximately 180,000 CFA Francs is necessary for the plane ticket, but this cash outlay is generally made by a relative who is already working in France. The first migrants had to sell cattle to finance their trip to France, but there is presently no need to raise money in Senegal as the trips are entirely financed through remittances. In one case a vacationing migrant who did not have his return ticket received funds via a postal money order for its purchase. This example emphasizes the

close relationship that exists between the the migrants in France and their families. The link between the migrant and his home community transcends the physical distance between them. Cash readily flows from France to Senegal to assist in household maintenance and in the continued flow of migrants.

Migration is always temporary, done primarily to send money back, and leads to eventual return to the Boundou. The large majority of migrants interviewed had held temporary and short-term jobs. Migrants state that they do not plan to stay permanently in France; most hold low-level jobs with no upward mobility and very little job security. Even those who have better jobs, for instance in automobile manufacturing, rarely find themselves in a secure position. From December 1982 to March 1983, for example, there was a major strike at the Flins Renault plant outside Paris. The main strike issue was the laying off of workers to streamline the plant and reduce overhead; in this case, the workers being laid off were migrant laborers. Several residents of the Boundou who were working at the plant took advantage of the strike to come home, though they were not sure they would be able to return to their job. Not only is their work situation rather precarious in most cases but many migrants are never able to find secure or permanent jobs so that most of them work for temporary employment agencies. Some who work for temporary employment agencies use this to their advantage. When they are laid off after being in France for several years they return home, a vacation that can be more flexible than if they had been using accumulated leave.

While in France, most migrants attempt to minimize their expenses by staying in migrant hostels where they room with kinsmen and fellow village members. This enables a migrant not only to minimize his expenses but places him in a familiar environment, surrounded by friends who are often from his village's age-set group. Although the living conditions are spartan, they cut down on costs and maximize his support group of familiar friends. In many cases migrant communities almost recreate a village environment and participation in tontines. Tontines are savings clubs bringing together groups of individuals who pledge to contribute a predetermined sum on a monthly basis, to a central fund. This fund is handled by each member of the tontine in turn.

There are, of course, risks associated with migration. For example, one of the migrants interviewed described an arduous trip from the Boundou to Paris that took over a week. After less than a week in France, he came down with a severe case of pneumonia and had to be hospitalized for three months before he was back on his feet and able to find a job. A large percentage of migrants (between 10 to 20%) spend long periods of time unemployed.

Certain migrants are attracted by the new style of fast city living and start life anew for a period of time. In one such case a migrant who spent almost twenty years in France, married there and raised a family which he eventually left to return to the Boundou. Several years later, one of his children was getting married and wanted him to be present at the wedding. A plane ticket was sent but he refused to leave his village and the wedding took place without him. Migrants live in two worlds and must periodically make a painful switch between them. This transition is so difficult that men who had retired from migration were much more willing to talk about their experience than migrants home on vacation. One migrant on vacation absolutely refused to talk about his experience in France, saying that it was a different world and he did not want to associate it with his village life in any way.

The number of migrants who do not return seems to be very small. No one in the village that had migrants away for extended periods of time was willing to assume that they would not return home. The transition between the two worlds is difficult, but reintegration into the village of origin is the rule, rather than the exception.

3.2.3. Remittances and Their Uses

As we indicated earlier in section 3.2.2., important sums of money are sent by migrants to their home villages. For a small village of the Mbaniou Zone with three migrants in France and one in another African country, the amount of remittances over a eight-month period was over 2 million CFA Francs. In a survey of remittances to six villages, representing 75 households, one village received over 4 million CFA Francs while another received only 25000 CFA Francs. The mode of remittances for the six villages is 1,700,000 CFA Francs. It is difficult to determine with certainty whether all the funds sent to a village are intended for that village. There are men in certain villages known as homme de confiance and who serve as a combination of banker and go-between. They receive money either to be held, invested or distributed as the sender requests. Funds sent to an homme de confiance in one village may be intended for another village. The project area, however, is generally a cohesive social unit, so it is fair to assume that even if all the remittances sent to one of the project villages are not intended for it, the funds will stay with in the area served by the project.

Postal money orders are not the only way money is sent back. Some migrants send sums of money through friends who are returning on vacation or bring back cash themselves when they come on leave.

The uses of remittances fall into several categories. The most common is for household maintenance and to make up for any subsistance deficit. However, the

migrant's primary personal objective is to use remittances to increase the size of his herd and acquire additional wives. This is followed by home construction, personal and family prestige, and community-oriented projects.

Letters sent by migrants generally precede the arrival of remittances and reflect their primary concerns: family maintenance, marriage negotiations and the purchase of cattle. Letters sent to migrants center on requests for funds, updates on marriage negotiations, and on cattle purchases.

A typical letter sent by a migrant includes very specific instructions on how funds are to be used. They list the recipients by name and the amounts of money they are to get. Funds are often earmarked for specific activities. A migrant may specify that a sack of millet be given to his father, that his mother receive six cakes of soap, that his first wife receive a certain sum, as well as his second wife's sisters. In one case the young brother looking after his cattle is assured that they will look for a horse for him when he returns on vacation, but in the mean time, to keep up the good work. The letter may finish with a cryptic note saying, give this amount to my friend and tell him to pursue what we had talked about before my departure. The migrant in this case is sending funds to help seal marriage negotiations that are being taken care of by a friend.

As stated above, remittances are primarily used to make up for any subsistence deficit in the household. Remaining funds are used for investment and household improvements. Investments consist mainly of the purchase of cattle and negotiations for second and third marriages. The importance of cattle purchases was illustrated in one village when the head of family, who works in France bought a lottery ticket and won a very large sum. When the money was sent back to the Boundou, the decision was made to purchase 50 additional head of cattle. The purchase was entrusted to a brother who was able to acquire over 65 head of cattle with the funds allotted.

Remittances also finance small shops run by migrants' wives or sisters. Twenty-five to fifty thousand CFA Francs may be sent specifically for such investments. Virtually all small shops in the villages are capitalized through remittances. Remittances also are used to build tin-roofed cement block or cement-plastered houses. These buildings usually consist of three main rooms off a long narrow veranda with two small rooms at either end of the veranda. The size and quality of the structure depend on the amount of money available to the migrant. Throughout the project zone virtually all the tin-roofed houses have been built by remittances except in a few villages where the marabout has been able to afford the construction of tin-roofed concrete structures.

Remittances are also used to finance important collective efforts; in several villages, for instance, the digging of wells was financed through the participation of migrants. This

kind of project may represent an investment of 600,000 to 1,500,000 CFA Francs divided among the 15 to 20 migrants from that village. In one case the village determined that there was a need to deepen the existing well. The cost of the deepening was estimated and communicated to the senior member of the community in France. Members of the community then divided the cost among those who were employed; in this particular case the assessment was of 50,000 CFA Francs for each of the 12 employed migrants from the village. Funds may also be used for other community projects such as building mosques. The importance to the community of having migrants abroad also reflects on the whole village during feasts such as the Korité. It should be noted, however, that collective use of funds is not always the case; in some villages the leading family has always assumed the responsibility for well construction and sees it as their right and obligation to continue. This kind of attitude does not encourage migrants who are not members of the leading family and caste to participate in community projects.

Remittances have also introduced innovation. In one case this involves two motorcycles (among the only motorcycles over 50 cc owned by individuals in the project area). One is a large 250 cc four-cycle machine that cost the owner 800,000 CFA Francs plus about 140,000 CFA Francs for shipment to Senegal. The other is a 100 cc two-cycle motorcycle. Both were used for transportation and for a time the owners of the 100 c motorcycle used it instead of a horse to draw water from the local well. The maintenance of the motorcycles has been a problem: they were both broken and unused as of August 1984. However, they have been the talk of the village, and have conferred prestige upon owners and their households. These vehicles represent a very sizable investment and indicate that the migrants are open to experimentation and innovation with their remittances.

3.2.4. Migrants and Vacations

Few migrants are able to return home on a yearly basis; generally they return to their village every two or three years, after they have accumulated two to three months of vacation time, or leave a job and hope to return to another one later.

The reception given a vacationing migrant is an event that demonstrates the utmost importance of migration in the social structure of the Boundou. A sheep is killed, a feast is organized with drums and dancing by women. The returning migrant visits other households where he is elaborately welcomed and greeted. In return he is visited in his compound where he presides, surrounded by friends and men from his age-set group. During his visit he is not expected to work. Though he may well supervise or check on his cattle, he will not often be found drawing water or working in the fields, even if he is

home during the agricultural season. The migrant spends much time in his household, and hopes that his wife or wives will be pregnant before his departure. He may also spend time traveling to other villages pursuing marriage negotiations and visiting friends and relatives. He may spend time negotiating cattle sales or finding and negotiating with a mason for the construction of a cement block house.

The vacationing migrant is treated with deference and respect in his household and elsewhere. He is usually at leisure, and better dressed in new traditional clothes than his fellow villagers. All this provides a powerful incentive to other young men to migrate as soon as they can. The feast and celebration that mark his return, and the way he is treated when he is home attest to the important role the migrant plays in his household and the village.

3.2.5. Returned Migrants

The mean age of retired migrants for the sample is 40. Most have spent five or more years working at very dull and hard jobs, living in rather austere conditions. Upon return, a migrant assumes the management of his herd and household. Retired migrants are not men of leisure. Unlike migrants on vacation they assume managerial responsibilities and participate in livestock and agricultural activities befitting their age.

Not all migrants have successful experiences. Some return after two or three years, never having been able to adjust to life in France or found a job. In some cases migrants have been unable to send money home, and return with very little to show for their sacrifice except for their experience.

Returned migrants play an important role in the village since the fruits of their migration have provided for their family. Successful ones typically have a large tin-roofed house, one or several wives, and much larger livestock herds than before. All this enables them to assume a position of authority or respect within the village.

3.3. CHANGE AND SOCIAL STRUCTURE

There is evidence of ongoing challenge to established social relations in the project area. This is causing friction both within villages and in some cases between villages. It is difficult to isolate the principal agents of this change or to determine their order of importance; however, migration plays a major role and along with the project itself is a major agent of change. Because of its institutional nature and services it brings to the area, the project has tended to crystalize conflict that would have otherwise remained muted.

The changes attributable to migration have occurred both at the individual and at the community levels. In some villages, for instance, slave and artisanal caste households have been able to improve their economic position considerably through labor migration. All castes within a village are likely to migrate since social status does not appear to be a determinant of labor migration. Migrants from lower and upper caste households have equal chances to succeed, and some lower caste households have done very well for themselves. This raises mild but unquestionable challenges to traditional social order within the village.

Some of the project programs have led to direct challenges of the established social order. A good example has been the project's introduction of functional literacy classes in Pulaar. The curriculum of the Pulaar program lasted three years, with classes being open to all villagers. In the Mbaniou Zone, 1983 marked the end of the first literacy program. To continue the program, project staff held a test to select the best students in each of the villages for training as teachers. The selection of former students to become teachers was done essentially on the basis of merit. In one village the best student was a young man from a slave caste household. He was given the responsibility for teaching classes in his home village and in several surrounding ones. Of course, this meant he would be teaching religious and chieftainship caste children as well as those from slave and artisanal castes. The upper caste family that gives the village its chief objected to this and asked that an upper caste student be made teacher. When the project staff refused this request, the chief notified them that the village would not participate in the continuing literacy program since it meant that upper caste children were to be taught by a slave caste youth.

Another example of friction between castes as a result of project intervention occured in the same village. The research and evaluation team gave malaria pills to participating villages. These were presented in a public forum and it was stated that they were intended for the village as a whole. In this particular village, the pills were never allocated throughout the village, but were all used within the chief's family. When a second such gift was being made, the project representative was approached quietly by a lower caste member requesting that the project give another box of pills for the lower caste households since they had not been able to share in the first allotment of pills.

The stronghold of the traditional social and historical order is not only evident within villages; it plays an important role in relations between settlements. This became obvious when an attempt was made to group villages together to work on demonstration plots using various methods to prevent erosion. One village that was to participate considered itself historically and socially superior to the others and refused to take part in the

collective effort. They felt that the effort should have been done on their terms, and that they should not have been asked to participate as equals with villages of lower status.

These are some of the most obvious manifestations of conflict precipitated by project interventions. However, in most cases conflict was not as obviously manifested. The village chief can play an important role in minimizing conflict within the village. In the project area it appears that villages with weak or unresolved leadership have more open conflict problems.

Leadership in the project villages is assumed by the eldest male survivor of the founder or founders of the village. The line of succession is from eldest brother to youngest brother and then on to the eldest son of the eldest brother. The leadership of the chief is an expression of the consensus opinion based on the village's leading family and its elders. If the leading family has not agreed on its leadership, or if the leadership is weak, support for major issues is more difficult to establish. Conflict can be an indication that the leadership is not consolidated or that there is some dissention between the senior men of the founding families about the abilities of the present chief. In villages where the chief is a strong leader and takes time to look after problems, neither caste conflict nor disputes between households will be too pronounced. In most villages of the project zone the leadership is well in-hand.

3.4. CONCLUSIONS

It is important to keep in mind that for a number of reasons, including sociocultural homogeneity and local politics, the project area was expanded and reorganized in 1980 into three zones, each of which have different resource endowments and strategies or orientations. One should also recognize that because of these factors and of difficulties in circulating back and forth across the escarpment, the Mbaniou Zone has received the bulk of infrastructural developments: ponds, roads and firebreaks, and project technical headquarters. This is quite natural, because of the previous greater isolation of the Mbaniou Zone, its greater geological suitability to ponds, and its higher abundance of range resources. Conclusions will therefore tend to apply more particularly to the Mbaniou Zone than to other areas; whenever conclusions are significantly different in the case of other zones, it will be underscored.

The basic setting of a strongly hierarchical settled agropastoral society is beset by a number of endogenous and exogenous factors promoting sociocultural change. The major endogenous factor is obviously the set of harsh climatological conditions which have led to a pattern of recurrent crises in the area. The essential symbiosis between agriculture and

livestock remains, but capital accumulation (essentially livestock) through agricultural surpluses has ceased to be possible for quite some time; as a whole, the area is not self-sufficient in grains. Furthermore, we believe that even if young adult males now away on migration had remained to farm for their families, there still would be a food deficit in most years.

We do not mean to imply that farming will cease to be the basic vocation, or orientation of project populations. It is still considered by people to be the appropriate venue of life; certain groups even maintain seasonal residences in two types of villages: one for the rainy season, and one for the rest of the year, when no water is available in the other settlement. However, migration has clearly come to replace agriculture as the way to secure part of subsistence and all of savings/investment requirements. Local nonagricultural income is yet much too limited to play a similar role. We have every reason to believe that long-distance migration will remain a major socioeconomic feature and factor of change in the area.

Livestock continues to play an essential role in social relations at the family, village and area level. They contribute, on the one hand, to soil fertility and on the other, to continued denudation around villages. Nevertheless, they bring in over 90 percent of agricultural income.

Over the last eight years or so, the average size of herds owned by families living in the project area, and its age/sex composition, have remained fairly constant. It turns out that that high cattle mortality has long prevailed in the area, and that part of the reaction was to maintain herd productivity through purchases of heifers. As mortality has been reduced through project interventions, the need to replace breeding stock has decreased -- although it remains substantial -- and offtake is still very low. Decreases in mortality therefore seem to have led to reduced outlays for purchases of replacement stock rather than in rapid expansion of standing herds. In our opinion, future gains in controlling cattle mortality will reinforce the same trend; purchases will be likely to decrease, and sales to increase, rather than lead to sharp increments in cattle holdings.

Less is known about small ruminants unfortunately, partly because baseline data is not available. We do know, however, that mortality in sheep and goats is proportionally greater than for large ruminants. The potential benefits to be derived from low-cost extension programs aimed at women stock owners appears to be considerable.

In spite of important food purchases by families in all project zones, levels of food consumption are low. In fact, the zone where food purchases per household were the highest in 1983-84 is also the one where the nutritional value of food intake per person is the lowest. Furthermore, there are wide divergences around the mean level of caloric

intake per person. For the lowest quarter of families, caloric intake was below 1,431 Kcal/person/day, whereas the most fortunate 25 percent of families had an intake superior to 2,400 Kcal/person/day. There is no doubt that this both springs from and contributes to, health problems and low agricultural productivity in the area.

The assessment of net impact from project activities is complicated by strong interactions between interventions, and the fact that some secondary benefits have been more substantial than gains from primarily intended purposes.

3.4.1. Roads and Firebreaks

Roads were built in the area to allow access to the pond sites; most were then turned into seven-meter wide firebreaks, suitable for travel. Three fire towers were also built, as part of the overall firefighting plan.

Comparisons of overall yearly rangeland burns before construction of firebreaks and of the present extent of burns, as well as ongoing observation during the project life, indicate that neither: (a) the extensive firefighting plan, nor (b) the firebreaks themselves have had a noticeable impact on annual burning. The effectiveness of firebreaks has proved to be minimal, because of the orientation of prevailing winds, the narrowness of firebreaks, and very fast vegetation regrowth. At the same time, the education effort designed to raise consciousness in the population's minds of the need for better bush fire management does not seem to have made much of an impact.

The basic problem is that total fire management in the area is technically possible only at costs entirely out of proportion with the benefits one would derive from protecting vast expanses of little used rangeland from fire. The only cost-effective way to deal with fires in vast low productivity areas is fire prevention rather than firefighting. However, this requires a difficult and long-term effort of dialogue and education with local populations.

Nevertheless, one of the most important aspects of project interventions is the impact that the establishment of this network of roads had on the area. Previously, the only means of communication available were cart trails. Roads have allowed villages in the area to become integrated into the local administration; traffic from government agencies and political parties has increased, and some private transporters have started to penetrate the area.

3.4.2. Ponds

The water catchment ponds have also had a positive, if limited, impact on the area. They enable herders to use range that would not have otherwise been accessible and push back the time when men must draw water for their cattle. However, long-term benefits from ponds are quite limited. Because of serious infiltration problems, they retain water for only a short period of time so that any benefits to cattle disappear by the end of the dry season. Similarly, relief on denuded areas around villages is too brief to stop the process of degradation. Furthermore, the current design of ponds requires some regular maintenance: removing excess accumulations of silt, controlling erosion and evaporation by revegetation of slopes, building dikes, etc. Nothing in the project's experience suggests that local populations have either the means or the incentives to take upon these tasks.

3.4.3. The Mbaniou Base

Many livestock projects are neither financially nor economically viable because of overwhelming infrastructural investments. In this particular case, however, the complete absence of any other infrastructure in the project area justifies such interventions as road building and the establishment of a technical base at Mbaniou, because of the many ancillary benefits from this infrastructure. Firstly, the establishment of the base to allow the outposting of veterinary staff has been a success. Because of support at the base, veterinary staff were assigned to small villages throughout the project zone. The base has also brought other government services to the area. The Ministry of Education has been able to send a teacher there, who started the first Francophone school in the zone. The Bakel health project has also taken advantage of these physical facilities; there is now medical personnel in the area for the first time.

3.4.4. Livestock Extension Services

The project has introduced the first regular delivery of veterinary services in the area, especially through the outposting of agents at the Mbaniou base and in many villages. This allows herders to consult with them, obtain advice and make them aware of any outbreaks of disease among their animals. We believe observed gains in morbidity and mortality of livestock are directly related to this original approach to extension services. There is also evidence that in larger villages, the supplemental feeding program initiated by the project has been adopted by some herd owners, although no priority in supplementary feeding seems to be given to lactating cows.

The project's livestock marketing program buys cattle from herders and sells them on the Bakel market, partly under pressure from local authorities. This resembles more a public service than efforts to maximize benefits to herders. The option of helping to organize cattle shipments to more promising regional markets like Goudiry and Tambacounda must be seriously explored. Marketing activities dealing with sheep also have excellent potential, especially as they may relate to the sharp annual rise in demand for Moslem holidays.

3.4.5. Other Extension Services

General extension activities took on after 1980 a relatively bold new orientation, and have been much more successful than anything attempted previously. The project administration deserves very high marks for moving technical and extension field staff to the Mbaniou base, and assigning Pulaar-speaking agents to various villages, or the Mbaniou base. By working so much closer to project populations, they have gained a greater degree of trust on the part of villagers, and a much better perception of day-to-day problems facing them.

3.4.6. Functional Literacy

Fluent Pulaar speakers were recruited and trained to teach literacy in certain villages. Classes have been extremely well received with a high level of attendance. The literacy classes, for children and adults, are conducted around useful herd management or village sanitation themes. A Francophone school was then opened in the Mbaniou Zone; there is no doubt that this school was well attended, and by better-prepared students because most had already achieved basic literacy in Pulaar.

3.4.7. Maison Familiale of Ndia

The village of Ndia hosts a Maison Familiale (rural family extension center), whose staff works in several villages of the Mbaniou Zone. They have been regularly monitoring the weight and growth of infants. With the help of the Maison Familiale, the villages of Ndia and Mbaniou have been able to obtain milling machines which are important time and labor savers for women.

It is therefore clear that project interventions have not just established infrastructure and delivery system, they have reinforced the endogenous factors of sociocultural and economic change at work in the area. However, due to the previous isolation and backwardness of the area, much remains to be done. There remains very strong obstacles to change and the adoption of new ideas and practices. In addition to harsh natural conditions and lack of local resources, attitudes will constitute a

considerable obstacle to such continued project objectives as fire prevention, closer management of herds, maintenance of ponds and firebreaks, and revegetation of denuded areas. Pond and firebreak maintenance as well as revegetation, are tasks requiring very substantial levels of effort for which, in our opinion, neither means nor incentives (be they individual, or community-wide) are present at this time. Experience also suggests that intercommunity cooperation will be even more difficult to secure. The final conclusion is that regardless of the level of project resources in the near future (likely to be low in any case), the most proper approach is to expand field level extension programs for basic human and livestock health and education. Over time, this will foster improvement in communications and change in attitudes essential to the continued search for appropriate and feasible solutions.

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APPENDIX

ADDITIONAL STATISTICS AND QUESTIONNAIRES

TABLE A1.

DISTRIBUTION OF FIELDS, BY SOIL TYPE AND BY ZONE

Zone	Soil Type		
	Seeno	Seebo	Jarwal
Mbaniou	89	34	56
Sinthiou Fissa	146	32	48
Ololdou	16	80	34

NOTES: Seeno: light sandy soil
Seebo: heavier, more compact soil
Jarwal: intermediate

TABLE A2.

DISTRIBUTIONAL ANALYSIS OF SMALL RUMINANT HOLDINGS, BY ZONE
(90% Confidence Level)

	Prob.	Quantile	Confidence interval
Mbaniou			
	.25	12	11 - 14
	.5	16	15 - 21
	.75	26	21 - 40
Sinthiou Fissa			
	.25	7	4 - 10
	.5	14	10 - 19
	.75	23	19 - 31
Ololdou			
	.25	25	20 - 37
	.5	38	34 - 52
	.75	59	43 - 99

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TABLE A3.

AGE/SEX DISTRIBUTION OF SHEEPS; ALL ZONES

Age	Rams	Ewes	
0 - 10 months	59	Pregnant Lactating Other	4 1 44
11 mos. - 4 yrs.	62	Pregnant Lactating Other	31 48 34
4 - 6 yrs.	5	Pregnant Lactating Other	8 5 7
Over 6 yrs.	0	Pregnant Lactating Other	0 3 0

TABLE A4.

AGE/SEX DISTRIBUTION OF GOATS; ALL ZONES

Age	Bucks	Does	
0 - 10 months	104	Pregnant Lactating Other	12 5 19
11 mos. - 4 yrs.	77	Pregnant Lactating Other	73 102 62
4 - 6 yrs.	2	Pregnant Lactating Other	25 26 26
Over 6 yrs.	0	Pregnant Lactating Other	5 6 12

TABLE A5.

DISTRIBUTIONAL ANALYSIS OF ADJUSTED AGRICULTURAL SALES PER HOUSEHOLD
(90% Confidence Interval)

	Prob.	Quantile	Confidence Interval
Mbaniou			
	.25	772.5	500 - 1,605
	.5	2,687.5	1,812 - 5,894
	.75	9,778	6,136 - 11,518
Sinthiou Fissa			
	.25	481	0 - 1,591
	.5	2,400	1,591 - 2,750
	.75	4,365	2,750 - 7,217
Ololdou			
	.25	1,950	1,387 - 3,167
	.5	3,775	3,166 - 6,500
	.75	6,962	4,619 - 10,775

Figure A1. Distributional Analysis Protein / person/day

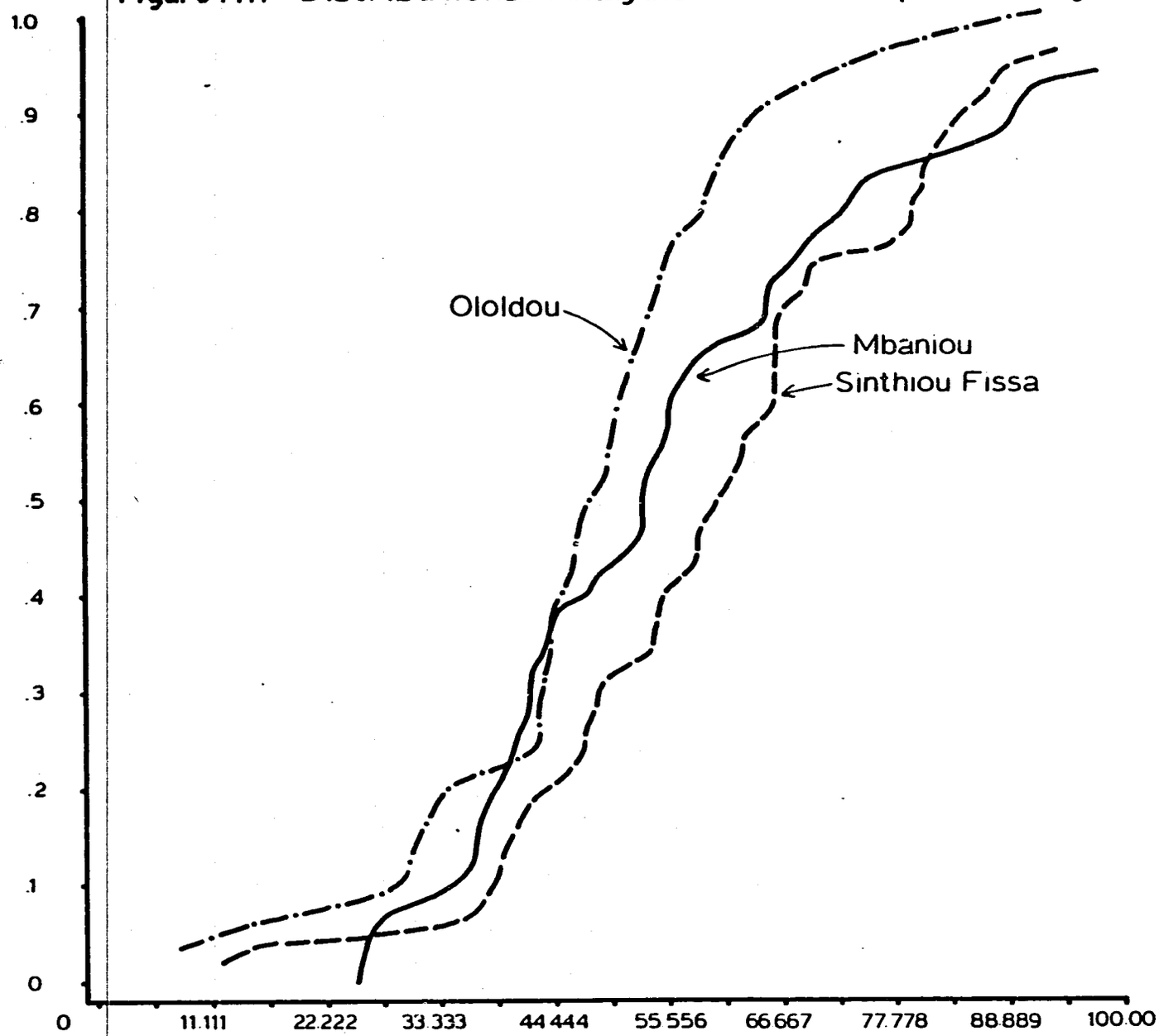


TABLE A6.

MBANIOU ZONE

CORRELATION MATRIX

(R at .1 level of significance = .3061)

Variable	Calor	Noemig	Sumarea	Totrecol	Hdcatl	Mncost
Calor	1.0000					
Noemig	-.0985	1.0000				
Sumarea	.1079	.1741	1.0000			
Totrecol	.2290	.2150	.6785	1.0000		
Hdcatl	-.1761	.1623	.0910	-.0116	1.0000	
Mncost	-.2820	.2219	-.1020	.1837	-.0584	1.0000

TABLE A7.

SINTHIOU ZONE
CORRELATION MATRIX

(R at .1 level of significance = .3783)

Variable	Calor	Noemig	Sumarea	Totrecol	Hdcatl	Mncost
Calor	1.0000					
Noemig	-.1335	1.0000				
Sumarea	.0918	1.4423	1.0000			
Totrecol	.3038	.2923	.1087	1.0000		
Hdcatl	-.2964	.2565	-.1905	-.2163	1.0000	
Mncost	-.0684	.4409	-.1834	.2336	.2924	1.0000

NOTES:
- Calor: Adjusted caloric intake, per person.
- Noemig: Migration indicator, per household.
- Sumarea: Total area cultivated by individual households.
- Totrecol: Quantities harvested by individual households.
- Hdcatl: Cattle ownership, per household.
- Mncost: Index of household food purchases.

TABLE A8.

OLOLDOU ZONE

CORRELATION MATRIX

(R at .1 level of significance = .3365)

Variable	Calor	Noemig	Sumarea	Totrecol	Hdcatl	Mncost
Calor	1.0000					
Noemig	.1760	1.0000				
Sumarea	-.0558	-.4115	1.0000			
Totrecol	.0414	.1654	.3684	1.0000		
Hdcatl	.5270	.2709	-.0603	.2473	1.0000	
Mncost	.2254	.4905	.1967	.6697	.4387	1.0000

TABLE A9.

ALL ZONES

CORRELATION MATRIX

(R at .1 level of significance = .1914)

Variable	Calor	Noemig	Sumarea	Totrecol	Hdcatl	Mncost
Calor	1.0000					
Noemig	.0044	1.0000				
Sumarea	.0732	.0507	1.0000			
Totrecol	.1151	.1811	.4676	1.0000		
Hdcatl	.0053	.1672	.0708	.0432	1.0000	
Mncost	.0833	.3481	-.0682	.3421	.0878	1.0000

NOTES:
- Calor: Adjusted caloric intake, per person.
- Noemig: Migration indicator, per household.
- Sumarea: Total area cultivated by individual households.
- Totrecol: Quantities harvested by individual households.
- Hdcatl: Cattle ownership, per household.
- Mncost: Index of household food purchases.

PROJET ELEVAGE DE BAKEL

ETUDE FUMURE/RENDEMENT

Etude Thématique A

Nom dossier H.P. FUMU [ ][ ] Observations No. ___ à ___ No. de Variables 10

Var. 1: Date _____ [AN][M][ ][ ][ ][ ] Var. 2: Saison _____ [ ]

Var. 3: Village _____ [ ][ ] Carré de _____ Var. 4: No. du Carré ____ [ ][ ]

Var. 5: Enquêteur _____ [ ][ ] Var. 6: No. du Champ: [ ][ ]

Var. 7: Culture actuelle (1983) _____ [ ][ ] Var. 8: Type de Sol _____ [ ]

EMPLACEMENT DU CHAMP PAR RAPPORT AU VILLAGE ET CARRE

NORD
(Sahal on Rewo)

Ouest
(Hirnage)

Village

Est
(Funnage)

SUD
(Baleeri ou Worgo)

Echantillon No. (Obs.)	FUMURE, MAI 1983 Var. 9: Quantité de Fumure, en grammes*	RENDEMENT, OCT/NOV 1983 Var. 10: Poids Récolté, en grammes**

*à l'intérieur d'un cercle ayant un rayon de 1.13m

**Sur une parcelle de 2 x 2m ($4m^2$)

PROJET ELEVAGE DE BAKEL

ETUDE THEMATIQUE B

CARRIERES DES REPRODUCTRICES

Nom dossier H.P. Carr [ ] Observations No. __ à __ No. de Variables 12

Var. 1: Date _____ AN [ ] M [ ] J [ ] Var. 2: Village _____ [ ] Carré de: _____

Nom de la Vache _____ Var. 3: No. d'Enquête de la vache [ ] Var. 4: Age de l'animal [ ]

Var. 5: No. de Vêlages [ ] Var. 6: No. d'avortements [ ] Var. 7: Provenance de l'animal: (1) Née dans le troupeau (2) Reçue en don (3) Reçue en prêt (4) Achetée [ ]

	LISTE DES PRODUITS				PRODUITS AYANT QUITTE LE TROUPEAU							
	Var. 8:	Var. 9: SEXE Male (1) Femelle (2) Castré (3)		Var. 10:	Var. 11: Explication du départ du produit							Var. 12:
Obs.	AGE		Code	Encore dans le Troupeau? Oui/Non	Mortalité? (Raison)	Perte?	Donné?	Prêté?	Vendu?	Abatu?	Code	AGE à la sortie

PROJET ELEVAGE DE BAKEL

INFORMATION DEMOGRAPHIQUE
(Fiche No. 1)

Nom dossier H.P. DEMO [ ][ ] Observations No. ___ à ___. No. de Variables 15

Var. 1: Date _____ A N M J [ ][ ][ ][ ][ ][ ]

Var. 2: Saison _____ [ ]

Var. 3: Village _____ [ ][ ]

Carré de _____

Var. 4: No. du Carré _____ [ ][ ]

Var. 5: Enquêteur _____ [ ][ ]

PERSONNES DU MEME MENAGE
(Mangent ensemble)

*Coranique (1)
Alphabet (2)

Obs.	Var. 6: Membre No.	Nom	Parenté	Var. 7: Sexe	Code	Var. 8: Age	Var. 9: Femme Enceinte? O/N	Code	Var. 10: Allaite? O/N	Code	Var. 11: Activité Principale	Code	Var. 12: Activité Secondaire	Code	Var. 13: Type d'Education*	Code	Var. 14: Années d'Education

Var. 15: Caste du chef de Ménage: _____

PROJET ELEVAGE DE BAKEL

EMIGRATION: DONNEES DE BASE

(Fiche No. 2)

Nom dossier H.P. EMIG [ ][ ] Observations No. ___ à ___ No. de variables 17

Var. 1: Date _____ A N M J [ ][ ][ ][ ][ ][ ] Var. 2: Saison _____ [ ] Var. 3: Village _____ [ ][ ]

Carré de _____ Var. 4: No. du Carré _____ [ ][ ] Var. 5: Enquêteur _____ [ ][ ]

I. EMIGRES ACTUELS: Quels membres de la famille ont quitté le village temporairement?

Obs.	Var. 6: No. Id	Nom	Parenté (voir Fiche 1)	Var. 7: Sexe	Code	Var. 8: Age	Var. 9: Raison*	Code	Var. 10: Quand Partis?	Code	Var. 11: Destination (ville, ou pays)	Code

II. ANCIENS EMIGRES: Quels membres actuellement au village ont émigré autrefois?

Obs.	Var. 12: No. Id	Nom	Parenté (voir Fiche 1)	Var. 13: Sexe	Code	Var. 14: Age	Var. 15: Raison*	Code	Var. 16: Durée Absence	Code	Var. 17: Destination (ville ou pays)	Code

*Raisons: commerce (1), école (2), travail (3); autre (4)

NOTA: Cette fiche doit être administrée une fois par carré seulement; au début de l'enquête.

PROJET ELEVAGE DE BAKEL

CHAMP INDIVIDUEL
(Fiche No. 3)

Nom dossier H.P. CHAM [ ][ ] Observations No. ____ No. de Variables 16

Var. 1: Date _____ AN [ ][ ] M [ ][ ] J [ ][ ] Var. 2: Saison _____ [ ]

Var. 3: Village _____ [ ][ ] Carré de _____ [ ][ ]

Var. 4: No. du Carré _____ [ ][ ] Var. 5: Enquêteur _____ [ ][ ]

Var. 6: No du Champ _____ [ ][ ] Var. 7: Culture Actuelle (1983) _____ [ ][ ]

Var. 8: Ce champ est cultivé principalement par _____ [ ][ ] (No. de membre, voir fiche No. 1).

Var. 9: C'est un champ de: village (1), brousse (2)? [ ]

CALCUL DE SUPERFICIE

Côté No.	Degrés	Distance	m	Côté No.	Degrés	Distance	m	Côté No.	Degrés	Distance	m

(mètres/pas ____) GAP: ____, Périmètre ____m. % Erreur ____

Var. 10: Superficie _____(ha) [ ][ ][ ][ ]

Var. 11: Nombre d'années depuis la dernière jachère? _____ [ ][ ] (si actuellement en jachère, inscrire:0)

Var. 12: Type de sol (p.e. seebo, seeno, jarval) _____ [ ]

"Combien avez-vous récolté sur ce champ l'année dernière?";

[ ][ ][ ] _____ (unités) de [ ][ ] KG chacune _____ kg.

Ou: Var. 13: Quantité totale estimée pour ce champ _____ kg. [ ][ ][ ][ ]

Var. 14: "Quelle culture y avait-il sur ce champ l'année dernière?" _____ [ ][ ]

Var. 15: "Quelle culture y avait-il sur ce champ il y a deux ans?" _____ [ ][ ]

Var. 16: "Quelle culture y avait-il sur ce champ il y a trois ans?" _____ [ ][ ]

PROJET ELEVAGE DE BAKEL

ENQUETE TRAVAIL AGRICOLE (Fiche No. 4)

Nom dossier H.P. AGRI [ ][ ] Observations ___ à ___ No. de Variables 13

Var. 1: Date _____ A N M J Var. 2: Saison _____ [ ] Var. 3: Village _____ [ ][ ]

Carré de: _____ Var. 4: No. du Carré _____ [ ][ ] Var. 5: Enquêteur _____ [ ][ ]

Obs.	Var. 6: Champ No.	Var. 7: Culture Actuelle	Code	Var. 8: Activité Agricole[a]	Code	Var. 9: No. d'heures de travail pour la famille[b]	Var. 10: No. d'heures de travail pour d'autres personnes[c]	EQUIPEMENT UTILISE[d] Var. 11: A Type	Code	Var. 12: Type	Code	Var. 13: Type	Code
	Voir Croquis des champs du carré			a/par exemple: Labourer semer ler sarclage (voir Tableau "Activités")		b/Membres réguliers du carré.	c/par exemple: amis; invités	d/par exemple: cheval, charrue, semoir, houe occidentale, outil manuel					

PROJET ELEVAGE DE BAKEL

CONSOMMATION ALIMENTAIRE
(Fiche No. 5)

Nom dossier H.P. ALIM [ ][ ] Observations No. ___ à ___ No. de Variables 14

Var. 1: Date | AN | M | J | Var. 2: Saison [ ] Var. 3: Village _____ [ ][ ]

Carré de _____ Var. 4: No du Carré ___ [ ][ ] Var. 5: Enquêteur _____ [ ][ ]

Visite commencée à ___ (heure) Visite achevée à ___ (heure)

Var. 6: Type de Repas 1er petit-dejeuner (1); 2ème petit-déjeuner (2); déjeuner (3); Diner (4)

_____ [ ][ ]

Var. 7: Si petit-déjeuner; restes du diner de la veille? (oui/non) _____ [ ][ ]

Pour tout repas: Nombre de rationnaires: Var. 8: No. d'Hommes _____ [ ][ ]

Var. 9: No. de Femmes _____ [ ][ ]

Var.10: No. d'Enfants _____ [ ][ ]

NOM DU PLAT PRINCIPAL _____

Obs.	Var. 11: Ingrédients	Codes	Var. 12: Poids en grammes	Var. 13: Provenance Vient du Ménage (1) d'un achat (2) d'un échange (3)		Si Reçu en Echange Var. 14: Contre quoi? Produit	Code

too narrow.

too wide.

PROJET ELEVAGE DE BAKEL

VENTES ET ECHANGES DE PRODUITS AGRICOLES ET BETAIL
(Fiche No. 6)

Nom dossier H.P. SORT [ ][ ] Observations No. ___ à ___ No. de Variables 12

Var. 1: Date _____ AN [ ][ ] M [ ][ ] J [ ][ ]

Var. 2: Saison _____ [ ]

Var. 3: Village _____ [ ][ ]

Carré de _____

Var. 4: No du Carré _____ [ ][ ]

Var. 5: Enquêteur _____ [ ][ ]

LISTE DES PRODUITS VENDUS OU ECHANGES DEPUIS LA DERNIERE VISITE

	VENTES														ECHANGES						
	Var. 6:		Var. 7: lieu de vente					Var. 8: Quantité				Var. 9: Prix		Var.10: Recettes	Var. 11: Echange		Var. 12: Quantite				
Obs.	Produit	Code	Autre Carré (1)	Marché Village (2)	Autre Marché (3)	Marchand Ambulant (4)	Code	No. d'Unités	Type d'Unité	Kg. par Unité	Total en Kg.	Par Unité	Kg	Totales CFA	Contre: Produit	Code	No. d'Unités	Type d'Unite	Kg. par Unité	Total EN	Total KG

LISTE DE PRODUITS

Mil (1)	Lait (4)	Mouton (7)	Cheval (10)	Gombo (13)	Riz (16) _____ (19)
Sorgho (2)	Poulet (5)	Chèvre (8)	Ane (11)	Beurre (14)	légumes (17) _____ (20)
Niébé (3)	Oeufs (6)	Bovin (9)	Arachides (12)	Maïs (15)	_____ (18)

PROJET ELEVAGE DE BAKEL

ACHATS ALIMENTAIRES, (PRODUITS POUR CONSOMMATION HUMAINE)
(Fiche No. 7)

Nom dossier H.P. ACHA [ ][ ] Observations No. ___ à ___ No. de Variables 11

Var. 1: Date _____ AN [ ][ ] M [ ][ ] J [ ][ ]

Var. 2: Saison _____ [ ]

Var. 3: Village _____ [ ][ ]

Carré de _____

Var. 4: No. du Carré _____ [ ][ ]

Var. 5: Enquêteur _____ [ ][ ]

Liste des Produits/Codes	Obs.	Var. 6: Produit	Code	Var. 7: Lieu d'Achat Au Village (1) Autre Village (2)	Var. 8: Quantite No. d'Unités	Type d'Unité	Kg/ Unité	Total en Kg	Var. 9: Prix CFA Par Unité	Par Kg	Var. 10: Cout Total (CFA)	Var. 11: Va Durer (...jours)	Liste des Produits/Codes
(1) Riz													(16) Sucre
(2) Mil													(17) Thé
(3) Sorgho													(18) Oigons
(4) Maïs													(19) Choux
(5) Huile													(20) Sauce tomate
(6) Viande boeuf													(21) Cubes Maggi
(7) Viande mouton/cheva													(22) Piment
(8) Poulet													(23) Poivre
(9) Oeufs													(24) Simbara (powder)
(10) Poisson frais													(25) Café
(11) " fumé/ séché													(26) Lait concentré
(12) Lait frais													(27) Cola
(13) Lait en													(28) Arachides
(14) Pain													(30) Diakhattu
(15) Sel													(31) Biscuits

PROJET ELEVAGE DE BAKEL

EVOLUTION DU BETAIL
(Fiche No. 8)

Nom dossier H.P. ANIM [ ][ ] Observations ___ à ___ No. de Variables 23

Var. 1: Date _____ AN [ ][ ] M [ ][ ] J [ ][ ] Var. 2: Saison _____ [ ]

Var. 3: Village _____ [ ][ ] Carré de _____

Var. 4: No. du Carré _____ [ ][ ] Var. 5: Enquêteur _____ [ ][ ]

CHANGEMENTS DEPUIS LA DERNIERE VISITE

I. BOVINS

	ENTREES						SORTIES					
	Var. 6: Type Male (1) Femelle (2)		Var. 7:		Var. 8: Naissance (1) Achat (2) Don (3)		Var. 9: Type Male (1) Femelle (2)		Var. 10:		Var. 11 Décédé (1) Vendu (2) Donné (3)	
Obs.	Castré (3)	Code	AGE	Code	Pret (4)	Code	Castré (3)	Code	AGE	Code	Prêté (4)	Code

PROJET ELEVAGE DE BAKEL

EVOLUTION DU BETAIL
(Fiche No. 9)

Nom dossier H.P. ANIM ☐☐ Observations ___ à ___ No. de Variables 23

Var. 1: Date _____ AN | M | J ☐☐☐☐☐☐ Var. 2: Saison _____ ☐☐

Var. 3: Village _____ ☐☐ Carré de _____

Var. 4: No. du Carré ___ ☐☐ Var. 5: Enquêteur _____ ☐☐

CHANGEMENTS DEPUIS LA DERNIERE VISITE

II. MOUTONS (Var. 6)

	ENTREES						SORTIES					
	Var. 7:		Var. 8:		Var. 9: Naissance (1) Achat (2) Don (3) Pret (4)		Var. 10:		Var. 11:		Var. 12: Décédé (1) Vendu (2) Donné (3) Preté (4)	
Obs.	SEXE	Code	AGE	Code		Code	SEXE	Code	AGE	Code		Code

III. CHEVRES (Var. 6)

	ENTREES						SORTIES					
	Var. 7:		Var. 8:		Var. 9: Naissance (1) Achat (2) Don (3) Pret (4)		Var. 10:		Var. 11:		Var. 12: Décédé (1) Vendu (2) Donné (3) Preté (4)	
Obs.	SEXE	Code	AGE	Code		Code	SEXE	Code	AGE	Code		Code

PROJET ELEVAGE DE BAKEL

SUIVI SANITAIRE DU CARRE

(Fiche No. 10)

Nom dossier H.P. SANT [ ][ ] Observations ___ à ___ No. de Variables 12

Var. 1: Date _____ A N M J [ ][ ][ ][ ] Var. 2: Saison _____ [ ] Var. 3: Village _____ [ ][ ]

Carré de: _____ Var. 4: No. du Carré _____ [ ][ ] Var. 5: Enquêteur _____ [ ][ ]

Obs.	Var. 6: Membre No.	Nom	Parenté	Var. 7: Sexe	Code	Var. 8: Age	Var. 9: Si Femme: Enceinte?	Code	Var. 10: Si mère: Allaite?	Code	Var. 11: Etat de Santé	bon(1) malade(2) né(3) décédé(4)	Var. 12: Nature de la Maladie	Code

PDA

PROJET ELEVAGE USAID de BAKEL

6

Village

Toure de Feu

Mare Amenagée

Cours d'eau

Escarpment ou Colline

Piste

Route Pavee

Route Non Revetue

Route Secondaire

Route Amenagee ou Pare-feu

Chemin de Fer

Echelle: 1:100.000

0 0.5 1 1.5 2 3 4 5

Kilometres

Carte basée sur les photographies aériens de Fevrier 1980; par Maryam Niamir Range Manager, DSPA/USAID, Dec. 1982. Reproduction graphique par Jane McCormick, Center for Research on Economic Development, University of Michigan, Ann Arbor, Michigan, Fevrier 1983.

Nyai

AAQ-933

de BAKEL

6 of 6

Nyarowal Pastures

Range Inventory Sites

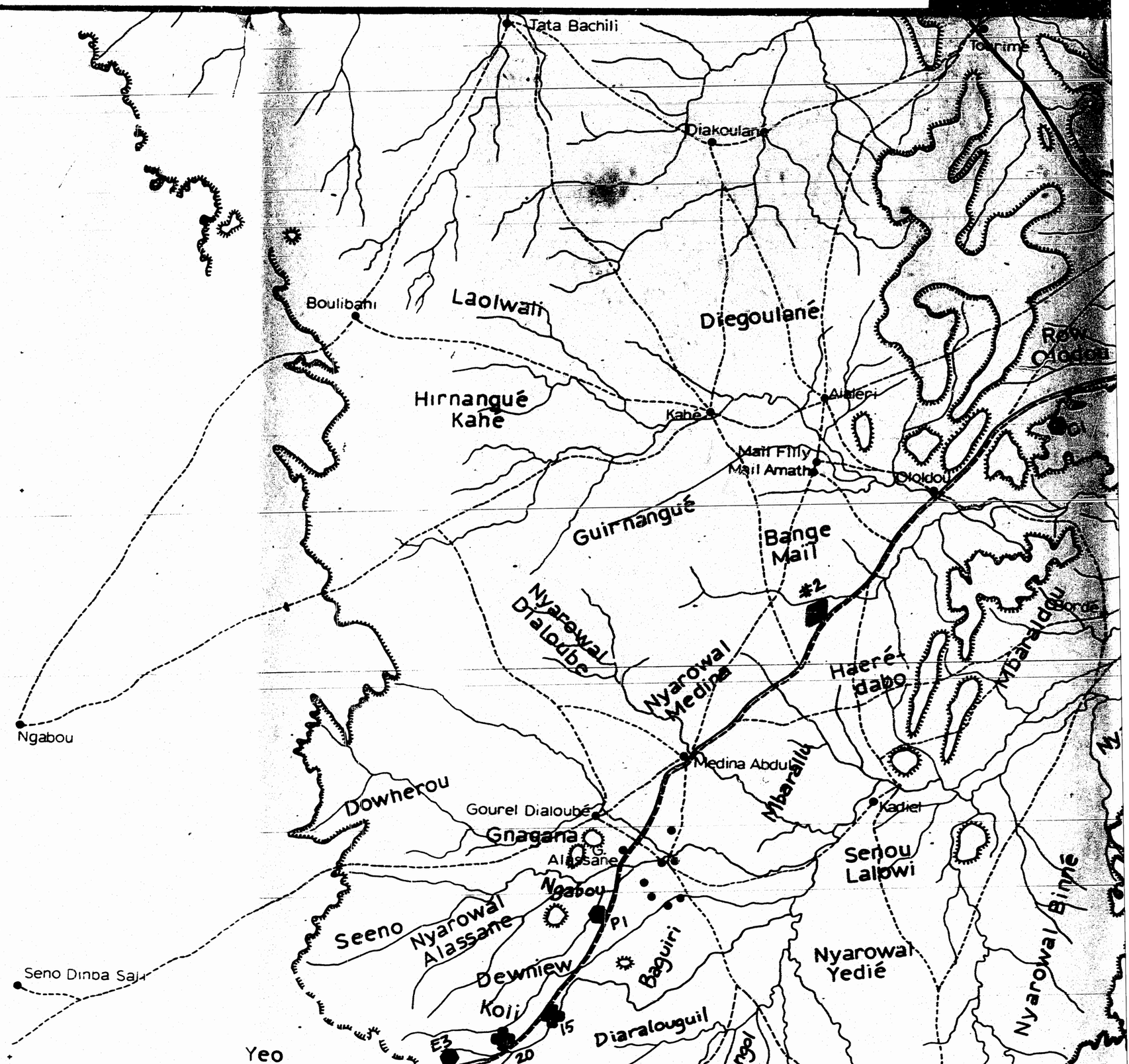
Soil Profiles

Permanent Enclosures

00

4 5

s de Fevrier 1980;
PA/USAID, Dec. 1982.
ick, Center for Research
Michigan, Ann Arbor,



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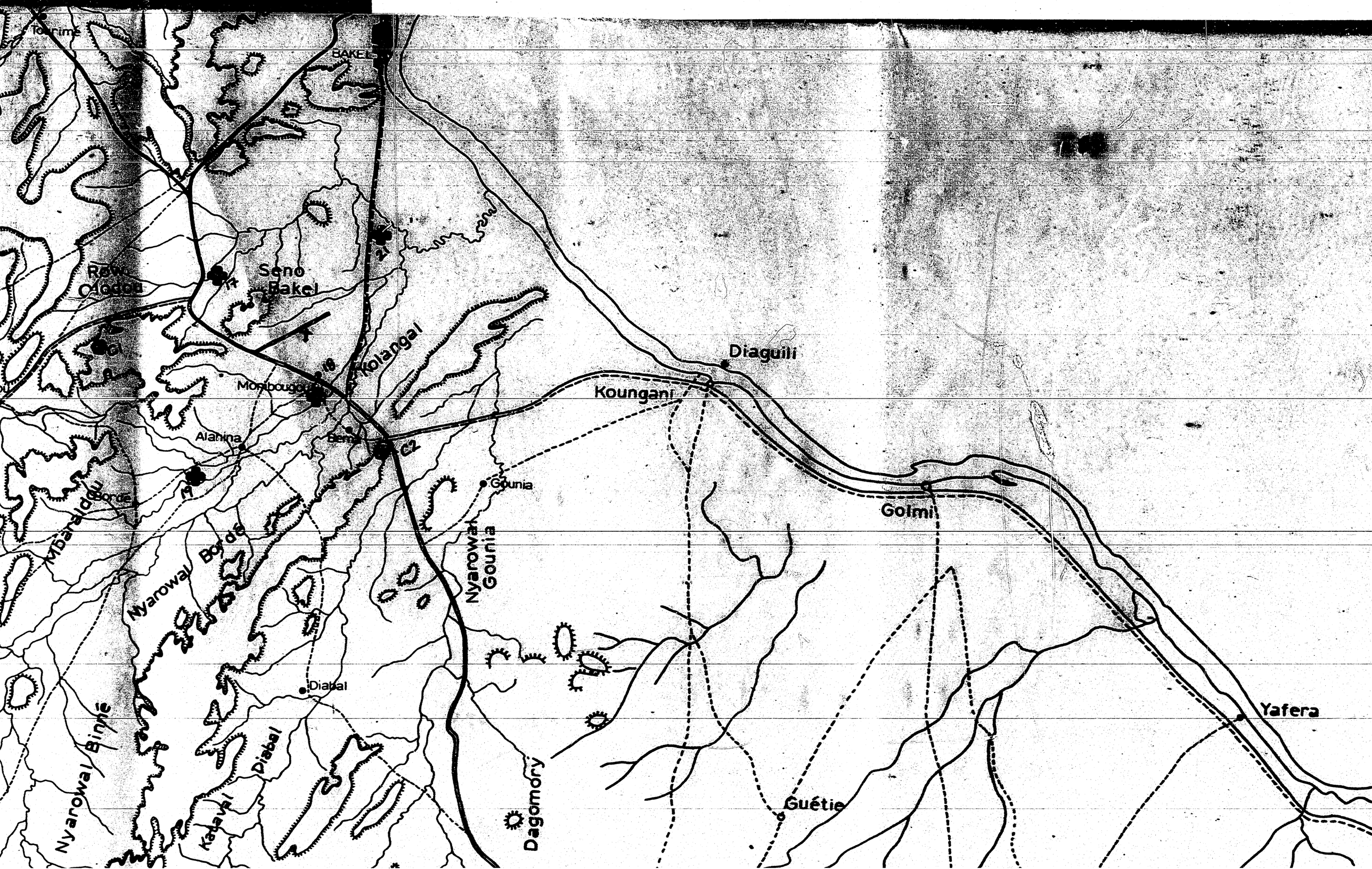
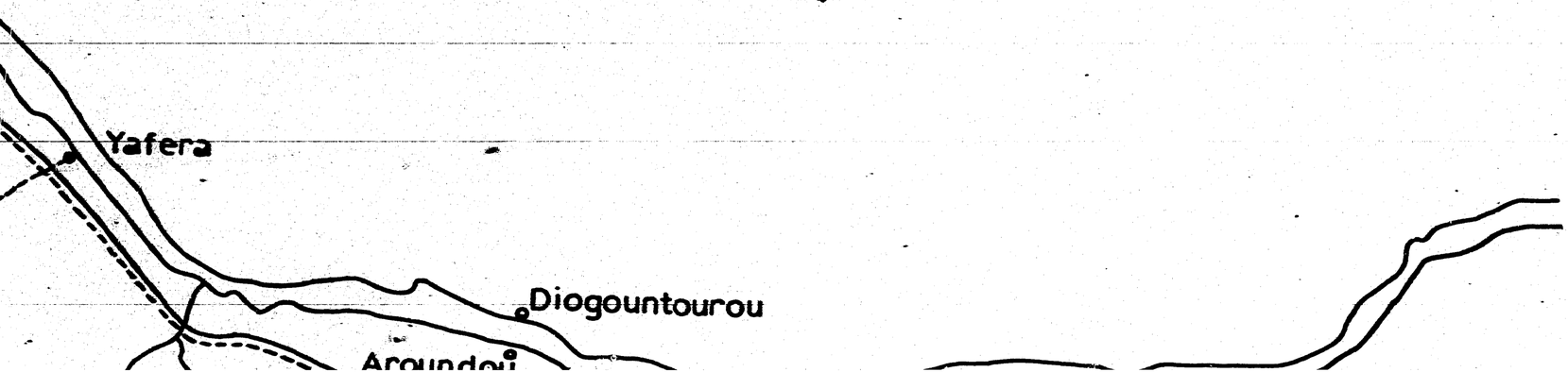
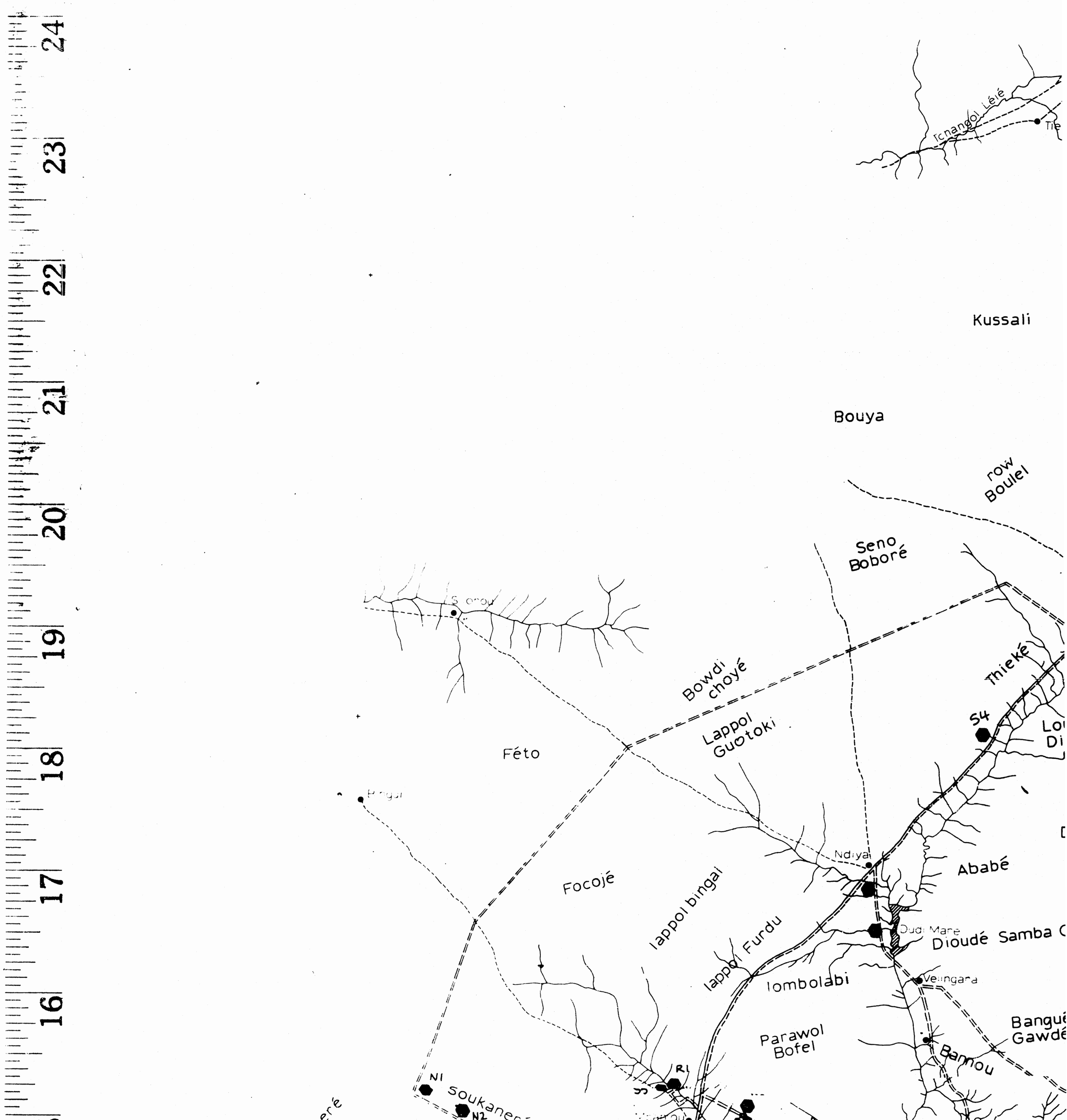


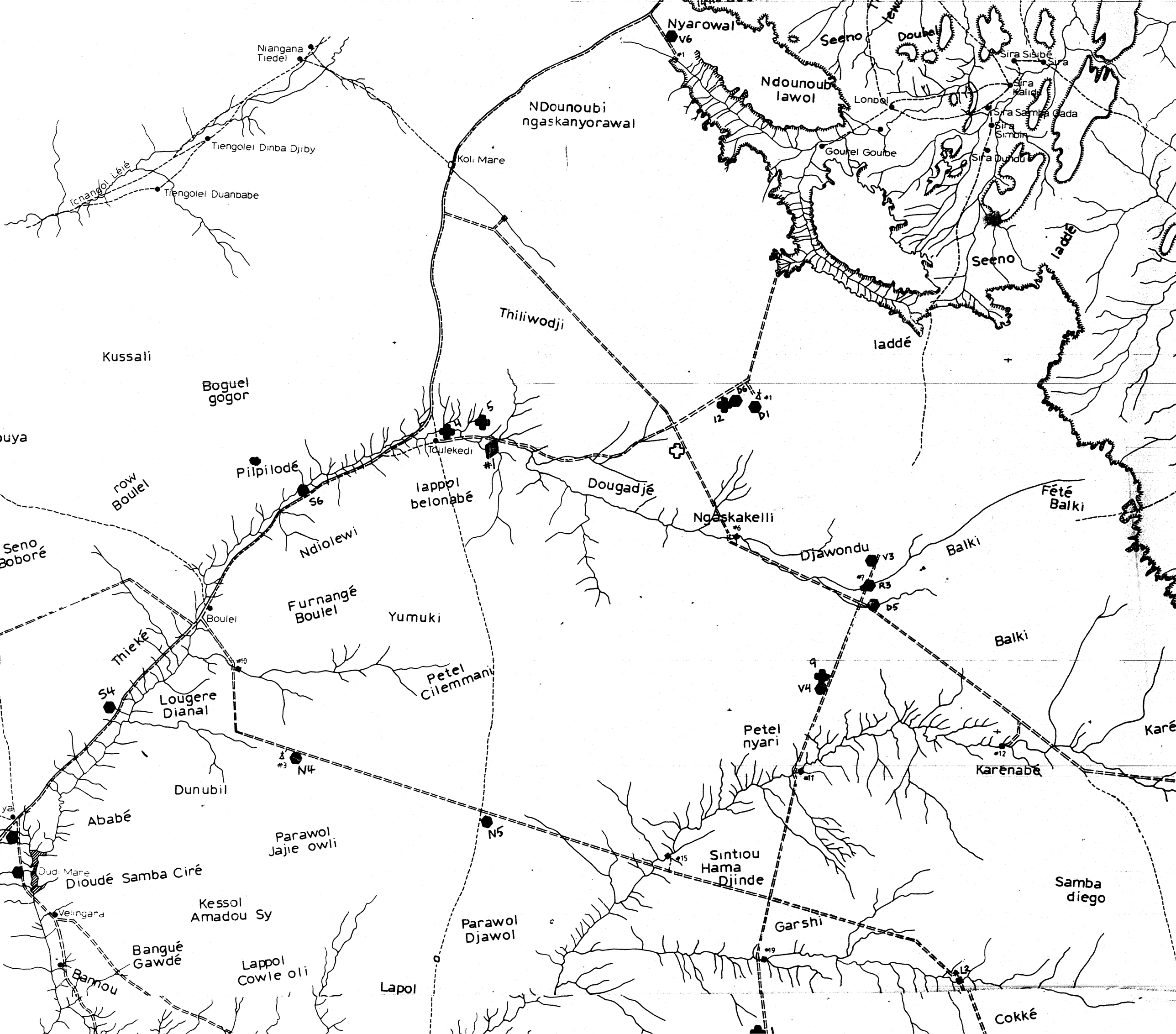
Tourimé
BAKEL
Seno Bakel
Kolangal
Diaguili
Koungani
Alahina
Gounia
Golmi
Nyarowal Gounia
Nyarowal Bordé
Diabal
Yafera
Guétie
Dagomory
Nyarowal Binné

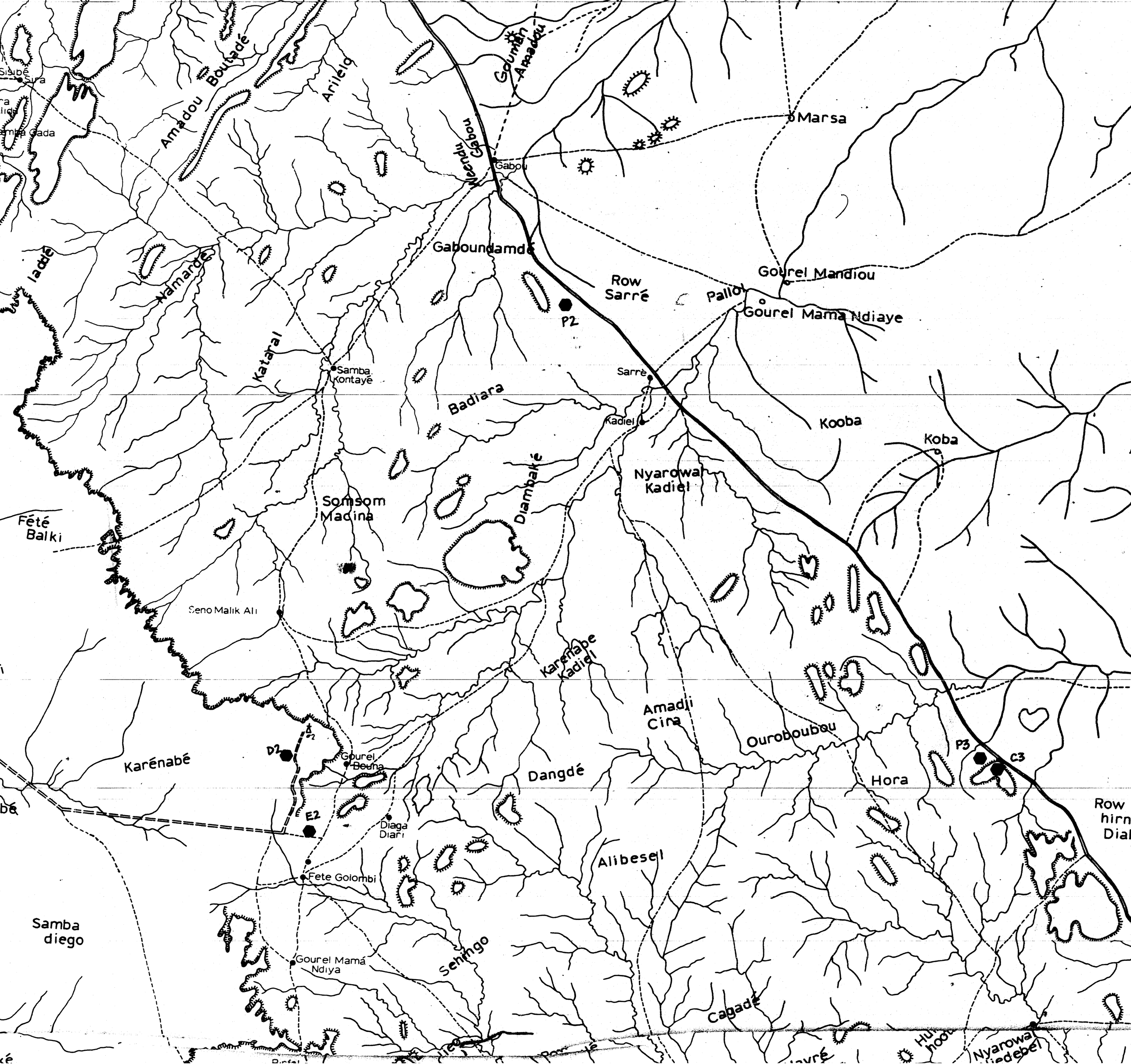
6



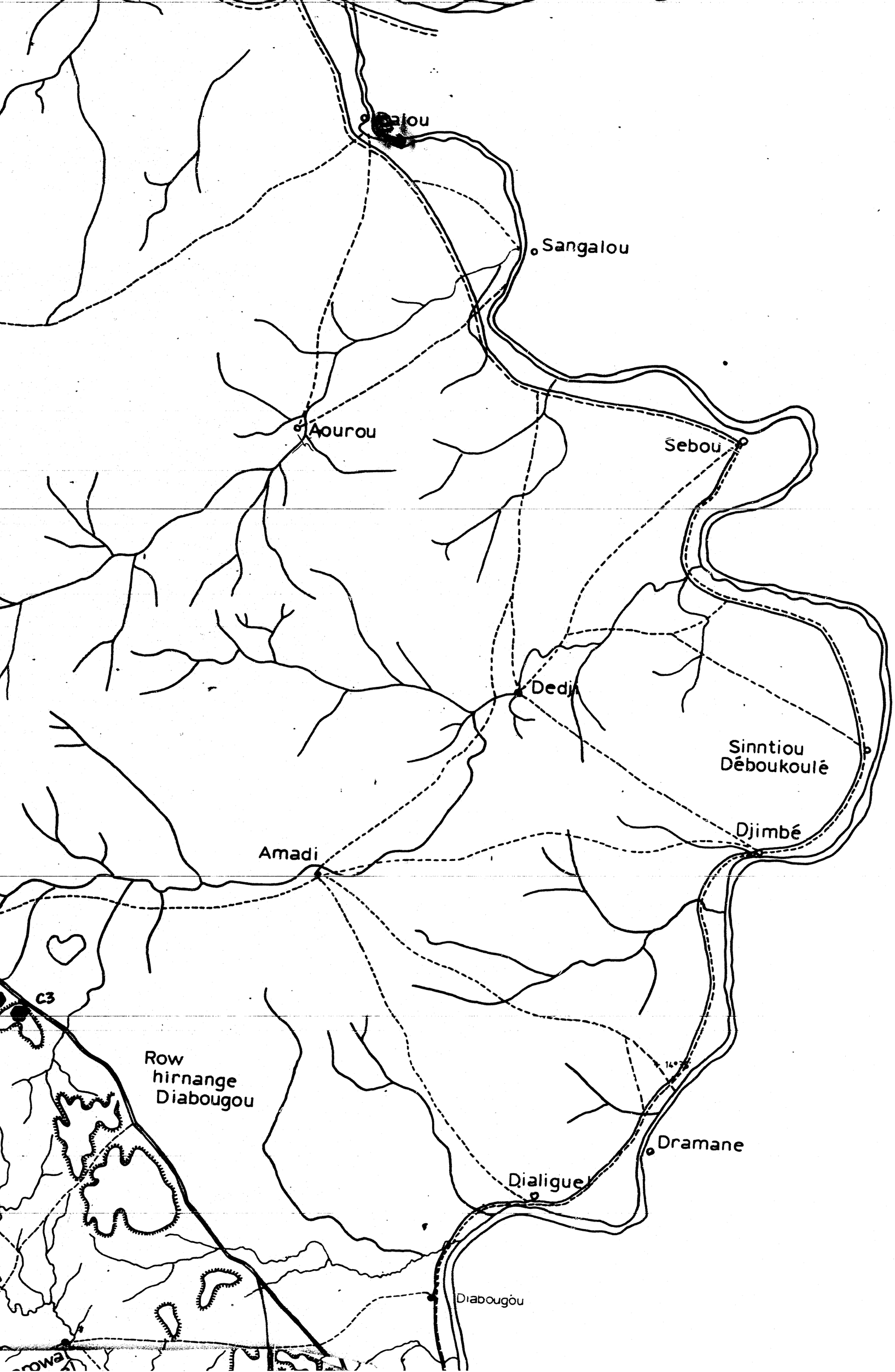


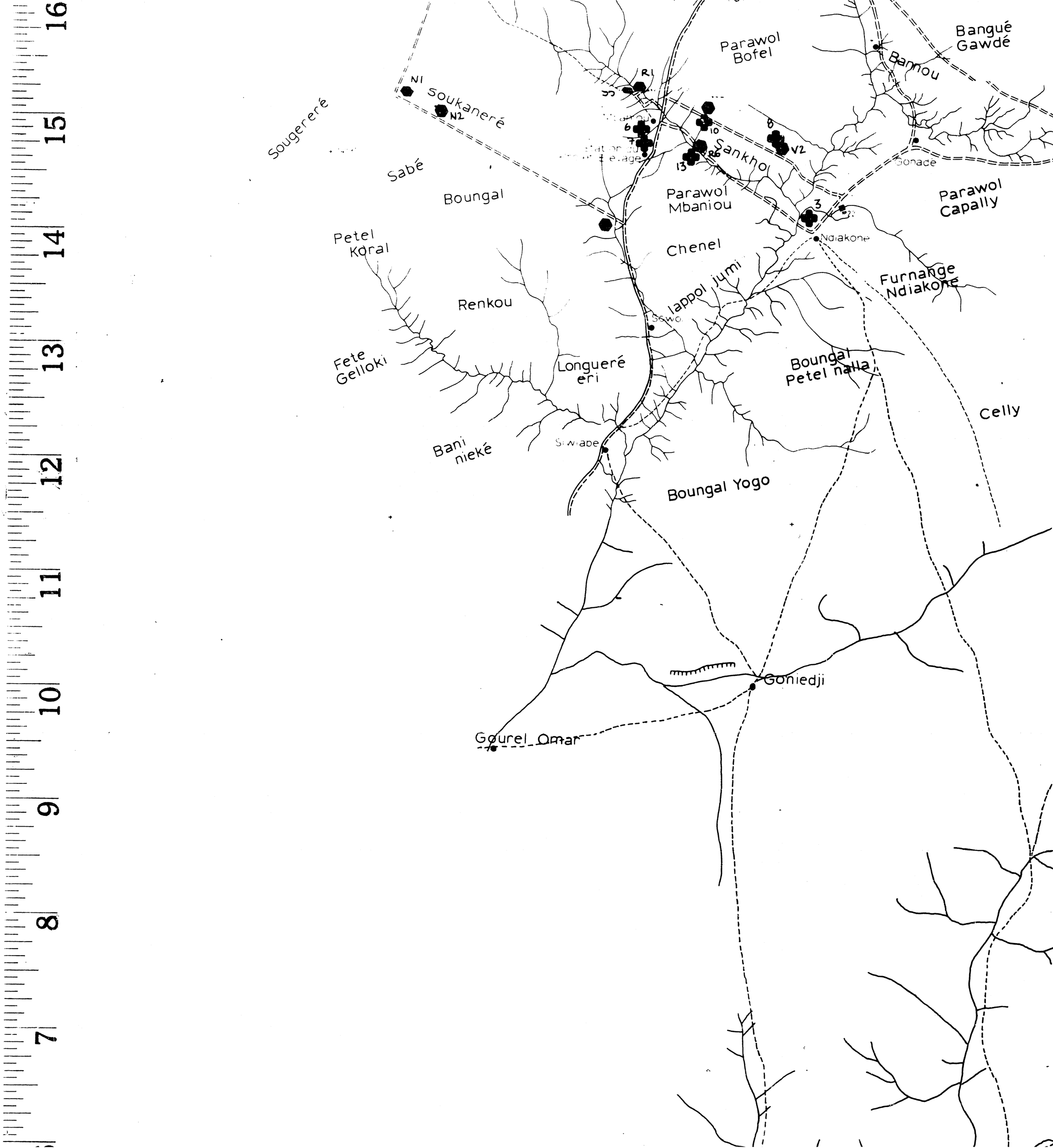
Tchangol Léié
Kussali
Bouya
row Boulel
Seno Boboré
Bowdi choyé
Lappol Guotoki
Féto
Thieké
S4
Ndiya
Ababé
Focojé
lappol bingai
lappol Furdu
Dudi Mare
Dioudé Samba
lombolabi
Parawol Bofel
Bannou
N1
N2
R1


Niangana Tiedel
Tiengolei Dinba Djiby
Tchangol Lélé
Tiengolei Duanbabe
Koli Mare
NDounoubi ngaskanyorawal
Nyarowal
V6
#1
Seeno
Doubel
Ndounoubi lawol
Lonbol
Sira Sisibé
Sira
Sira Kalidi
Sira Samba Gada
Sira Simbin
Gounel Goubé
Sira Dundu
Seeno
laddé
laddé
Thiliwodji
Kussali
Boguel gogor
buya
row Boulel
Seno Boboré
Pilpilodé
S6
Toulekedi
#1
5
4
lappol belonabé
Dougadjé
Ngaskakelli
#6
D6
#1
D1
12
Fété Balki
Ndiolewi
Djawondu
V3
#7
R3
D5
Balki
Balki
Boulel
Furnangé Boulel
Yumuki
Thiéké
#10
Petel Cilemmani
S4
Lougere Dianal
9
V4
Petel nyari
#11
#12
Karenabé
Kare
#3
N4
Dunubil
Ababé
N5
Parawol Jajie owli
#15
Sintiou Hama Djinde
Samba diego
Dioudé Samba Ciré
Kessol Amadou Sy
Parawol Djawol
Garshi
#19
L2
Bangué Gawdé
Lappol Cowle oli
Lapol
Cokké

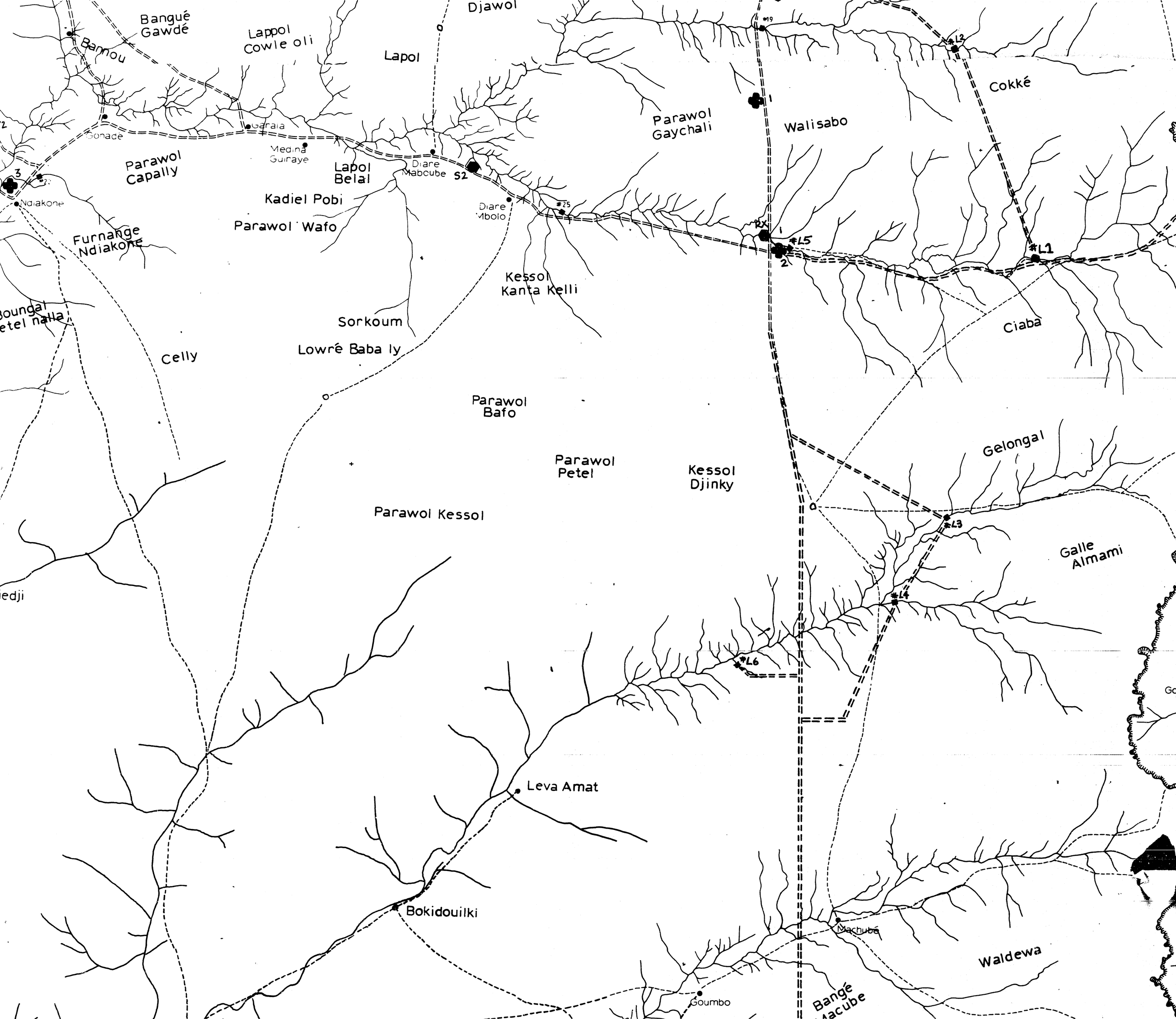


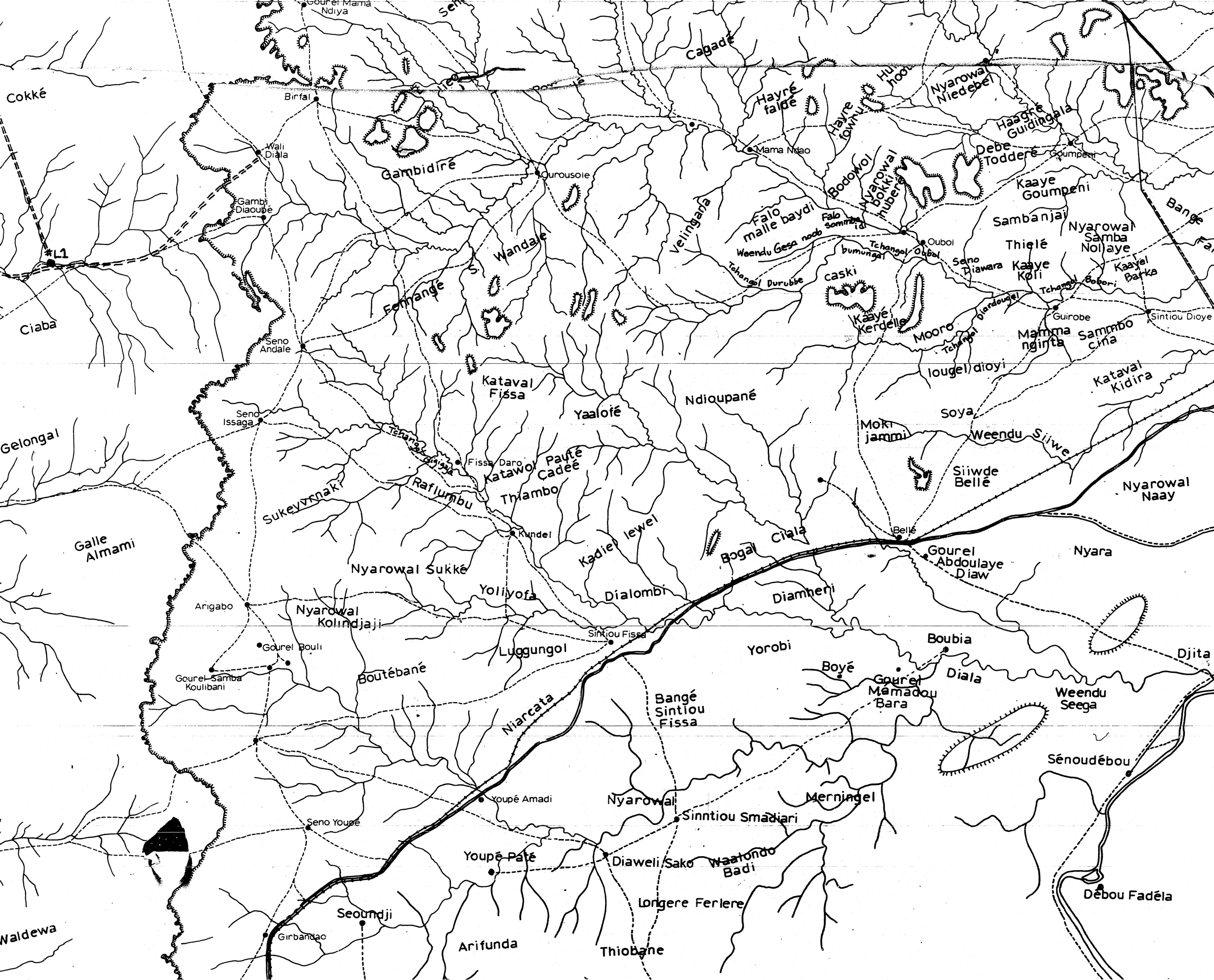
Sisibé
Sira
Amadou Boutadé
Arileiq
Gouman Amadou
Marsa
Weendu Gabou
Gabou
Gaboundamdé
Iaddé
Namardé
Row Sarré
Gourel Mandiou
Pallol
Gourel Mama Ndiaye
P2
Kataral
Samba Kontayé
Sarrè
Badiara
Kadiel
Kooba
Koba
Diambaké
Nyarowal Kadiel
Somsom Macina
Fété Balki
Seno Malik Ali
Karenabe Kadiel
Amadji Cira
Ouroboubou
P3
C3
Karénabé
D2
Gourel Bouna
Dangdé
Hora
E2
Diaga Diari
Alibesel
Fete Golombi
Samba diego
Gourel Mamá Ndiya
Sehingo
Cagadé
Nyarowal


Sangalou
Aourou
Sebou
Dedji
Sinntiou
Déboukoulé
Djimbé
Amadi
C3
Row
hirnange
Diabougou
Dramane
Dialigue
Diabougou

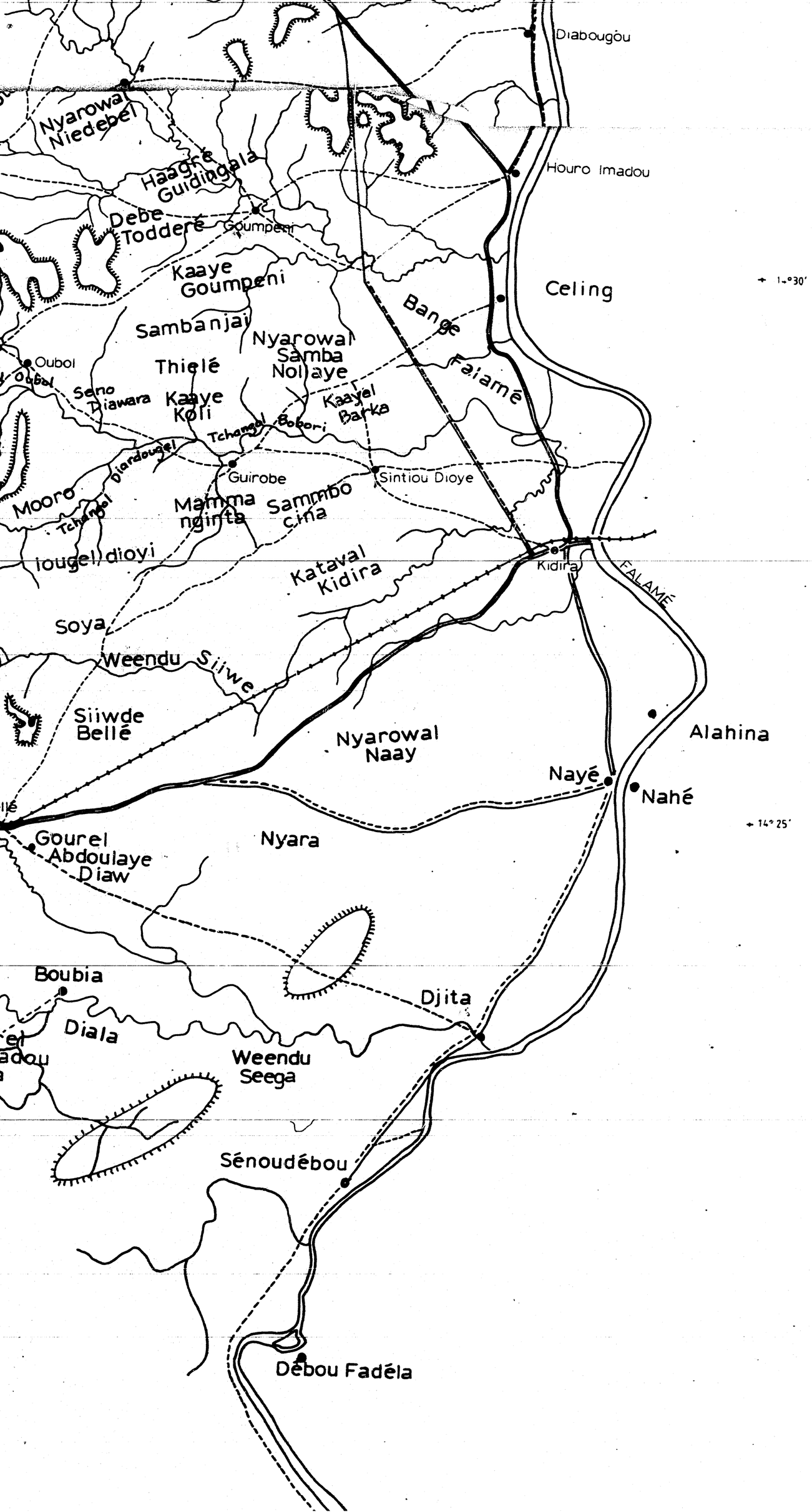


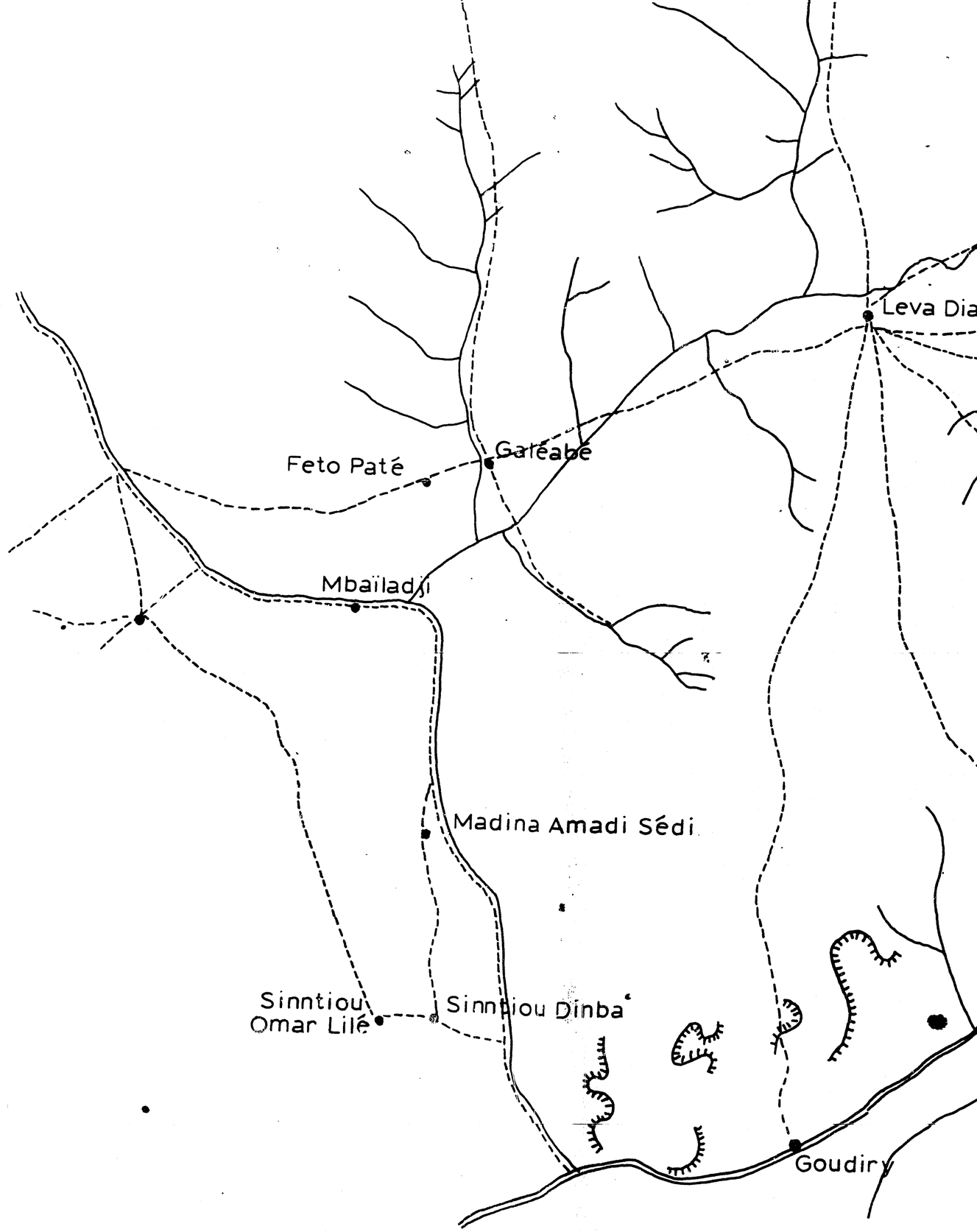
Parawol Bofel
Bangué Gawdé
Bannou
N1
Soukaneré
N2
Sougereré
R1
6
7
10
8
V2
13
R6
Sankho
Gonadé
Sabé
Boungal
Parawol Mbaniou
3
Parawol Capally
Petel Koral
Chenel
Ndiakone
Furnange Ndiakone
Renkou
Iappol jumi
Fete Gelloki
Longueré eri
Boungal Petel nalla
Celly
Bani nieké
Boungal Yogo
Goniedji
Gourel Omar

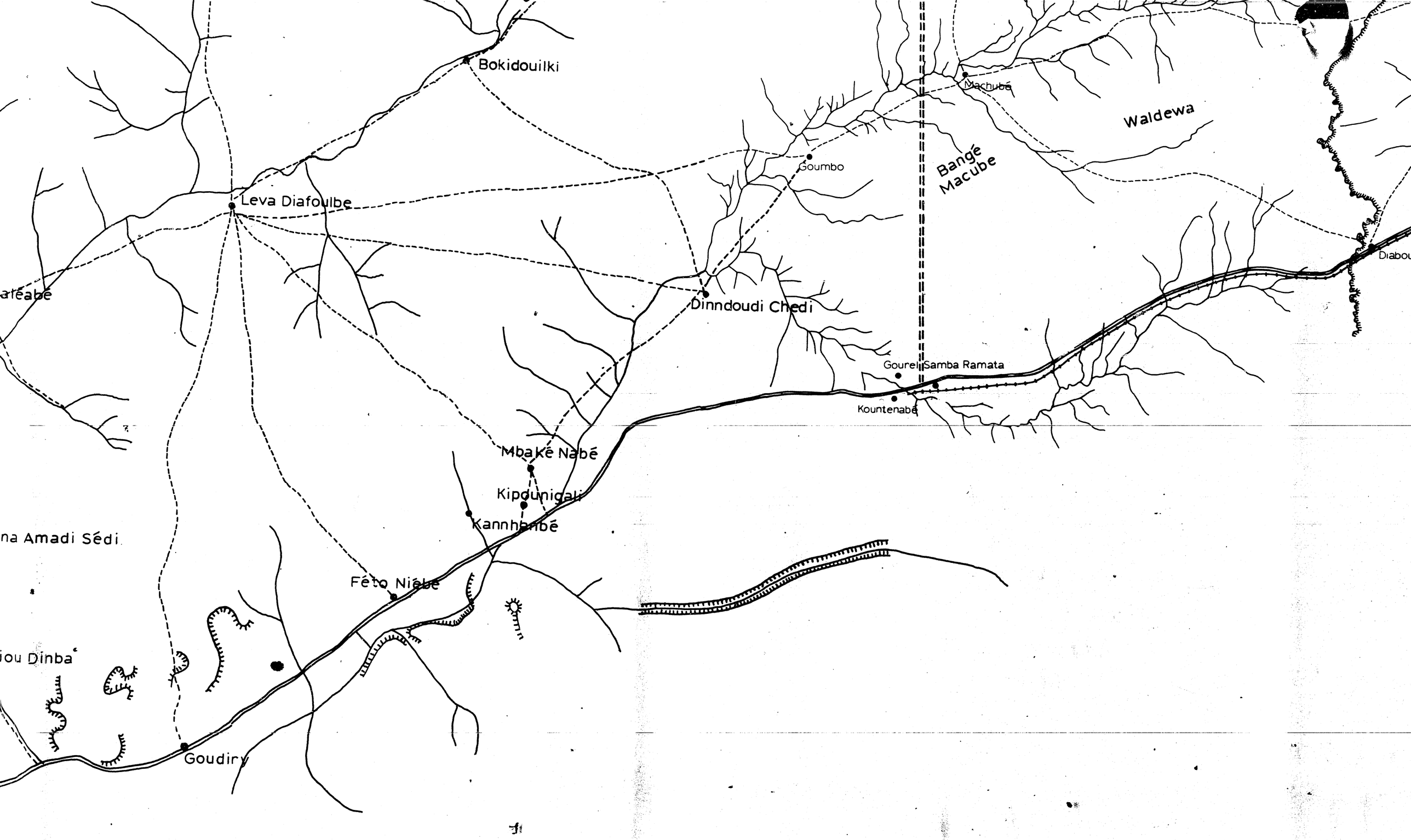

Bangué Gawdé
Bannou
Lappol Cowle oli
Lapol
Djawol
#19
#L2
Cokké
Parawol Gaychali
Walisabo
Gonade
Garala
Medina Guiraye
Parawol Capally
Lapol Belal
Diare Mabcube
S2
Kadiel Pobi
Diare Mbolo
#25
Ndiakone
Parawol Wafo
Furnange Ndiakone
#L5
#L1
Kessol Kanta Kelli
Sorkoum
Ciaba
Lowré Baba ly
Celly
Parawol Bafo
Gelongal
Parawol Petel
Kessol Djinky
Parawol Kessol
#L3
Galle Almami
#L4
#L6
Leva Amat
Bokidouilki
Machubé
Waldewa
Goumbo
Bangé Macube

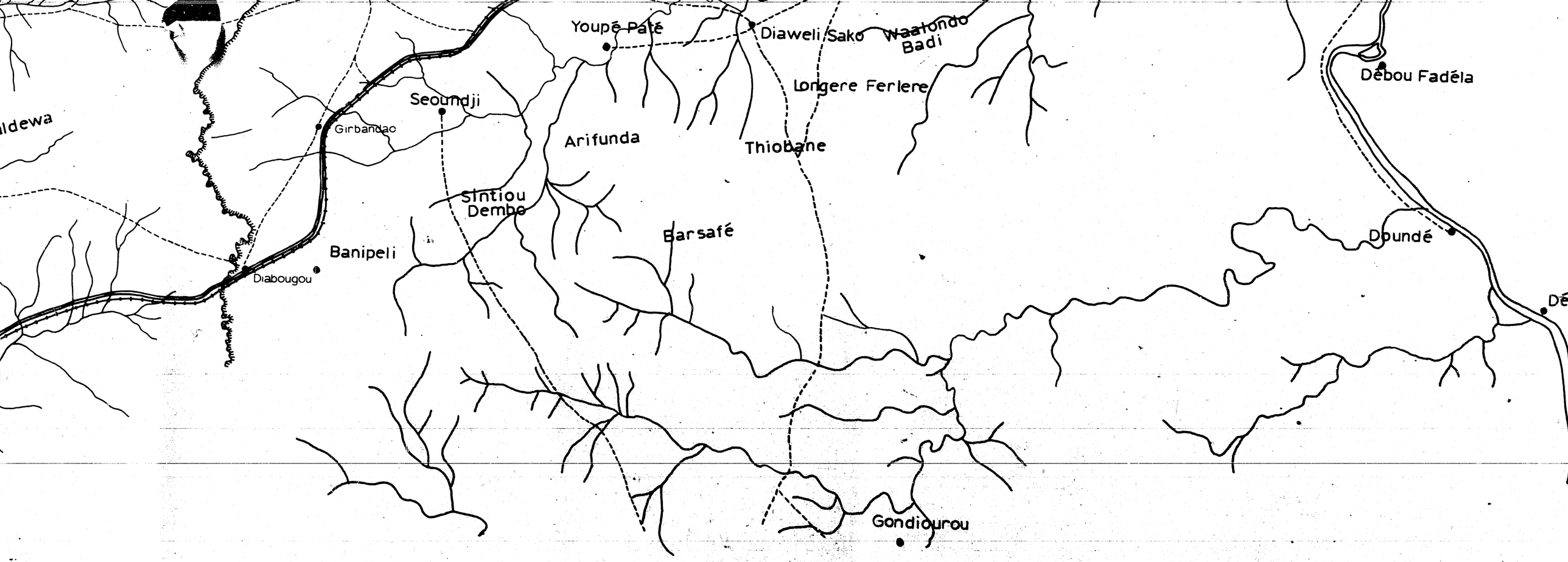


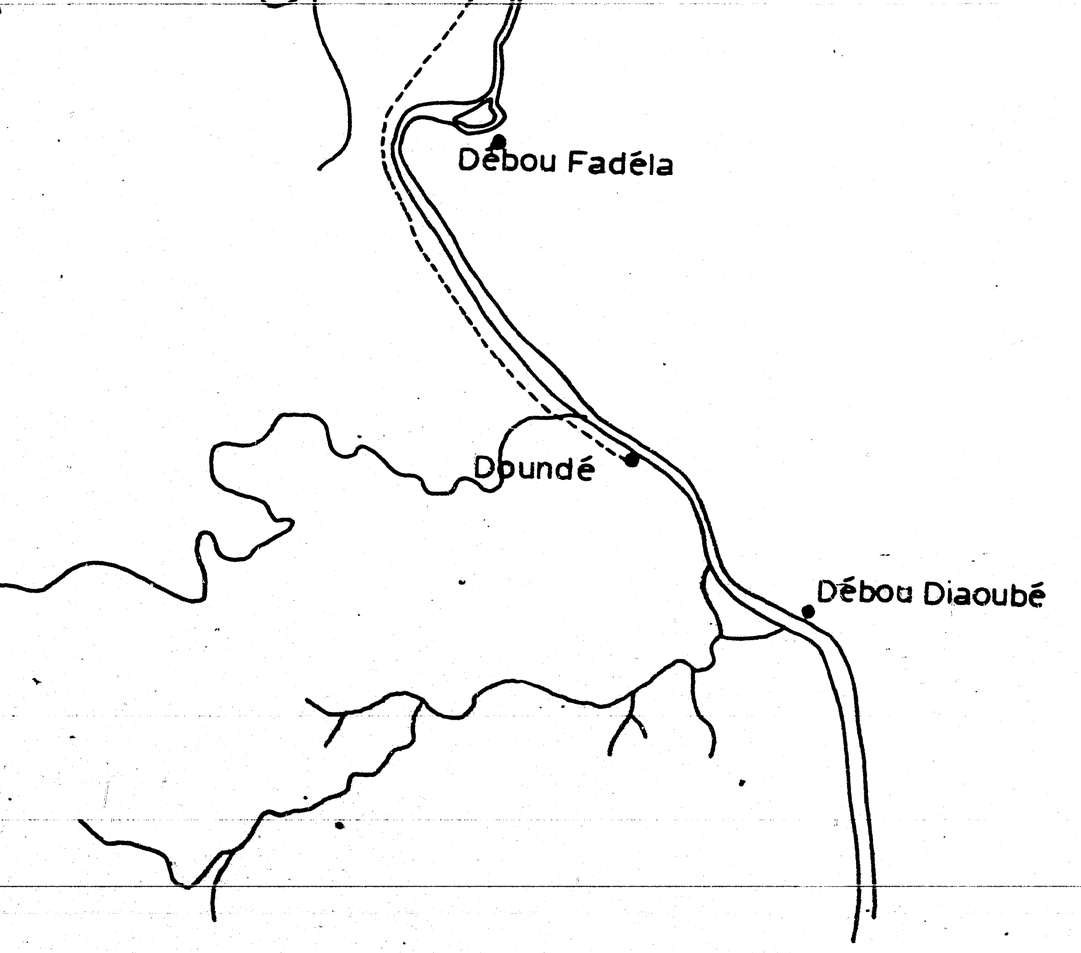
Gourel Mama Ndiya
Cagadé
Cokké
Birfal
Hayré faldé
Hayre fowru
Nyarowal Niedebel
Haagré Guidingala
Wali Diala
Mama Ndao
Debe Toddere
Goumpeni
Gambidiré
Ourousole
Bodowol
Nyarowal bokki hubere
Kaaye Goumpeni
Gambi Diaoubé
Velingana
Falo malle baydi
Falo sommba
Sambanjai
Nyarowal Samba Nollaye
Bange
#L1
Weendu Gesa noob
Tchangol Oubol
Oubol
Thielé
Wandale
Tchangol Durubbe
bumungal
Seno Diawara
Kaaye Koli
Kaayel Barka
Fennangé
caski
Tchangol Bobori
Ciaba
Kaayé Kerdelle
Mooro
Tchangol Diardougel
Guirobe
Sintiou Dioye
Seno Andale
Mamma nginta
Sammbo cina
lougel dioyi
Kataval Fissa
Kataval Kidira
Ndioupané
Yaalofé
Soya
Seno Issaga
Moki jammi
Weendu Siiwe
Gelongal
Tchangol Gigigaja
Fissa Daro
Katawol
Pauté Cadeé
Siiwde Bellé
Raflumbu
Thiambo
Nyarowal Naay
Sukeyvrnaki
Kundel
Kadiel lewel
Bogal
Ciala
Bellé
Galle Almami
Gourel Abdoulaye Diaw
Nyara
Nyarowal Sukké
Yoliyofa
Dialombi
Diamheri
Arigabo
Nyarowal Kolindjaji
Sintiou Fissa
Boubia
Gourel Bouli
Luggungol
Yorobi
Djita
Boyé
Gourel Samba Koulibani
Boutébané
Gourel Mamadou Bara
Diala
Weendu Seega
Niarcata
Bangé Sintiou Fissa
Sénoudébou
Youpé Amadi
Nyarowal
Merningel
Seno Youpé
Sinntiou Smadiari
Youpé Paté
Diaweli Sako
Waalondo Badi
Débou Fadéla
Longere Ferlere
Seoundji
Waldewa
Girbandao
Arifunda
Thiobane


Diabougou
Nyarowal Niedebel
Haagré Guidingala
Houro Imadou
Debe Toddere
Goumpeni
Kaaye Goumpeni
Celing
Bange
Sambanjai
Nyarowal Samba Nollaye
Oubol
Thielé
Faiamé
Seno Diawara
Kaaye Koli
Kaayel Barka
Tchangol Bobori
Guirobe
Sintiou Dioye
Mooro
Tchangol Diardougel
Mamma ngirta
Sammbo cina
Iougel dioyi
Kataval Kidira
Kidira
FALAMÉ
Soya
Weendu
Siiwe
Siiwde Bellé
Nyarowal Naay
Alahina
Nayé
Nahé
Gourel Abdoulaye Diaw
Nyara
Boubia
Djita
Diala
Weendu Seega
Sénoudébou
Débou Fadéla
14°30'
14°25'


Leva Dia
Feto Paté
Gaféabé
Mbaïladji
Madina Amadi Sédi
Sinntiou
Omar Lilé
Sinntiou Dinba
Goudiry


Bokidouilki
Machubé
Waldewa
Goumbo
Bangé
Macube
Leva Diafoulbe
Diabou
Dinndoudi Chedi
Gourel
Samba Ramata
Kountenabé
Mbaké Nabé
Kipounigali
Kannhanbé
Féto Niébé
Goudiry


Youpé Paté
Diaweli Sako
Waalondo
Badi
Longere Ferlere
Débou Fadéla
Seoundji
Girbandao
Arifunda
Thiobane
Sintiou
Dembe
Barsafé
Banipeli
Diabougou
Doundé
Gondiourou


Débou Fadéla
Doundé
Débou Diaoubé